THROUGH THE DEPTHS OF SPACE

A Primer of Astronomy

HECTOR MACPHERSON, JUN.

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From a Photograph *by Dr Max Wolf.*

THE PLEIADES.

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BY

HECTOR MACPHERSON, JUN.

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PREFACE.

THE object of this little book is to give in simple language a comprehensive idea of the Universe. It is intended to supply a felt want, and does not aspire to be an exhaustive text-book of the science of astronomy; neither does it aspire to deal with the mathematical and instrumental sides of the science. The use of technical phrases has been as far as possible avoided, so that the beginner may have no difficulty in thoroughly mastering the book and in proceeding to the more advanced works on the subject.

The writer has to record his sincere obligations to several gentlemen for their kindness in lending the plates accompanying the volume. To Messrs A. & C. Black he is indebted for Plates II., III.,

and VI.; to Professor Max Wolf, of Heidelberg, for Plates I., VII., and VIII.; to Professor Lowell, of Flagstaff, Arizona, for Plate IV.; and to the Rev. James Baikie, of Ancrum, for Plate V.

BALERNO, MID-LOTHIAN,
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Through the Depths of Space:

A Primer of Astronomy.

CHAPTER I.

OUR OWN PLANET—ITS PLACE IN NATURE.

The Study of Astronomy. — From the earliest ages the mind of man has been fascinated by the study of the heavenly bodies — Sun, Moon, and Stars. The observation of the heavens has always had a peculiar attraction for the more thoughtful members of the human family. Consequently, the name of the "founder of astronomy," if there ever existed such a personage, is lost in the mists of antiquity. We do not know who discovered the brighter planets, or who first observed the apparent motion of the Sun, or who grouped the stars into constellations. But we know this — that these constellations were recognised at the time of the ancient Greeks and Hebrews. Homer

and Hesiod refer to the cluster of the Pleiades, and to the constellation of Orion. In the Bible, too, we meet with frequent allusions to the celestial bodies. Job refers to the Pleiades, Orion, and other groups of stars, and, it has been thought, also to the planet Venus.

The ancient peoples suffered, however, from one serious drawback. The Chaldeans, Greeks, and Egyptians were themselves the pioneers of astronomical observation. They had not the advantage of centuries of valuable observations for consultation, as we—their more fortunate successors—have; and as a consequence they fell into many mistakes. As was only natural, the ancient peoples believed the Earth to be the centre of the Universe, about which all the heavenly bodies revolved, and for the benefit of which all the stars had been created. They had no idea of what the stars really are; but they regarded the Sun as a useful body to warm and illuminate the Earth, and the Moon and stars as convenient secondary light-givers.

Early Theories.—The views of the ancient peoples regarding the Sun were extremely crude, not to say amusing. The Sun, for instance, was believed to be no larger than Greece. The old astronomers did not know that the Earth was a globe; they thought it was a vast illimitable plain; and yet they knew that the Sun rose in the east every morning and set in

the west every night. Accordingly they devised some most remarkable explanations as to how the Sun reached the east again after apparently setting in the west—for they did not know that the Sun could travel *below* the Earth. They imagined that as the Sun sank in the west, it was caught by the god Vulcan, who was waiting to save it from falling into the western ocean. He placed it in his boat and rowed with it round to the east; on arriving there he shot it up with terrific force into the sky to commence another day's journey. Other ideas were equally unreal. By-and-by it became evident that the Earth must be a globe poised in space, and this was the view held by the well-known philosopher Aristotle. But although he believed it to be a globe, he held firmly to the idea that it was the centre of the Universe. His astronomical successors, Hipparchus and Ptolemy, had a well-reasoned, elaborate theory of the motion of the Sun and planets round the Earth. Ptolemy studied the question as to whether the Earth rotated on its axis, and rejected the theory on the ground that if the Earth moved there would be such a rush in the atmosphere as would carry men off its surface. Ptolemy believed that Sun, Moon, planets, and stars revolved round the Earth in the following order: the Moon, Venus, Mercury, the Sun, Mars, Jupiter, Saturn, and the stars proper, which were supposed to be attached to the inside of a large

sphere, of which the Earth was the centre. In order to explain the irregular planetary movements, it was necessary to make the planets revolve in circles, and the centres of these circles revolve round the Earth in larger circles. This theory was held for 1400 years, and the first man who openly challenged it was Nicolaus Copernicus, a canon in the cathedral of Frauenburg, in Poland.

The Copernican System.—Copernicus spent most of his life in trying to solve the motions of the planets. Ptolemy's theory was so complicated that Copernicus came to doubt it, and eventually to disbelieve it. He came to the conclusion that the irregular planetary motions could be better explained by the revolution of the planets and the Earth round the Sun, and the Moon round the Earth. He also thought that instead of all the stars revolving round our planet from east to west every twenty-four hours, it was more natural for the Earth to rotate on its axis in the opposite direction in the same time. Regarding Ptolemy's argument about the air, Copernicus pointed out that the atmosphere was carried along with the Earth in the same manner as a man who is wearing an overcoat carries it with him.

Copernicus published his great book, 'De Revolutionibus Orbium Cœlestium,' in 1543, and died on the day of its publication. The new theory was not

acceptable. Men still liked to think the little Earth the most important thing in the Universe. Even the great Danish observer, Tycho Brahe, did not accept the new view, but put forward a theory of his own, a mixture of the views of Ptolemy and Copernicus. According to the "Tychonic System," all the planets revolved round the Sun, and were carried by it round the Earth. Gradually, however, men accepted the Copernican theory, but the Church of Rome, which believed implicitly in Aristotle and Ptolemy, prohibited the sale of Copernicus's book.

Copernicus being dead, it was Galileo who was the sufferer for upholding the new theory. His discovery of the satellites of Jupiter in 1610, which showed a miniature of the Solar System, made him absolutely certain that the views of Copernicus were correct. In 1632 he published a book upholding the new doctrines, for which he was summoned before the Pope in Rome and compelled to recant his views. This he probably did out of fear of death, for in 1600 Giordano Bruno had been burned in Rome for the "crime" of declaring that the Earth was not the centre of the Universe. Thanks to men like Copernicus, Galileo, and Kepler, the new system was fully established in spite of opposition from both the Church of Rome and the conservative men of science and it was only in the seventeenth century that real progress was made in the science. For as long as the idea held sway that the Earth was the centre of

the Universe, the growth of astronomy was hindered and the outlook of astronomers narrowed.

With the appearance of Copernicus, astronomy was started on a new path, a path in which it was enabled to develop naturally—namely, the path of truth and progress. Copernicus, it is true, merely substituted the Sun for the Earth as the central body of the Planetary System. But this was itself a great step forward. The inhabitants of the Earth could no longer consider themselves the chief object of creation, or think that the Sun, Moon, and stars were made to revolve round the Earth and give it light and heat. The Earth was brought down from its proud position as centre of the Universe to the humble place of a small planet revolving round the Sun. These labours of Copernicus, supplemented by those of Tycho Brahe, Galileo, Kepler, and Newton, gave us a true conception of the planets, and told us one at least of the marvels of astronomy—namely, that this Earth of ours, which seems to us so immense and immovable, is whirling through space at the amazing rate of eighteen miles in one second of time. Of course, for many years this discovery made by Copernicus was disbelieved; and indeed in a sense it is no wonder that people disbelieved it, for if we give the idea a moment's consideration, it is difficult even to-day to imagine that our dwelling-place is dashing onwards through space with so great a velocity. The Earth seems so still that nothing tells us of the motion

of our planet, except the apparent motion of the Sun, which results from the movement of the Earth.

Gravitation.—What Sir Isaac Newton did was to show why our Earth is constantly moving round the Sun. Even the great Kepler had very hazy notions on the question of why the planets revolved. He thought that each planet was controlled by an angel of its own—a pretty idea, but an erroneous one. It was in 1666, when Isaac Newton was a young man in his ancestral home near Grantham, in England, that his mind first lit on the grand idea of the law of gravitation—that every body attracts every other body. Some biographers have thrown doubts on the well-known story of the fall of the apple leading Newton's mind to compare the apple and the Moon; but there is no reason why the story should not be true. At all events, Newton, who knew that a force of gravity existed in the Earth, was led to ask if the same force did not control the Moon in its orbit round the Earth. After twenty years' work he was able to show that the force which drew the apple to the ground held the Moon in its orbit. From this he found that the Earth revolved round the Sun simply by virtue of the power of gravity inherent in both the Sun and the Earth; and from this, again, he was led to his grand deduction that every particle of matter in the Universe attracts every other particle. Newton was never able to say what this great power

was. We are still unable to tell the cause of gravitation; but the more we think of that marvellous law which holds the Earth to the Sun, and the Sun to the system of the stars, the more marvellous and awe-inspiring does the great law become. In this branch of science we are still in the position of Newton, for the great ocean of truth lies undiscovered before us, as it did before him.

To prove the Earth merely one of a family of similar orbs revolving round the Sun was to take our planet down from the high position of ruler of the Universe and put the Sun in its place. The next marvel was to prove that the Sun itself was not the ruler of the Universe, but merely one of a family of similar stars, a member of what is called the Stellar System. The man who diverted astronomy into this entirely new path was a German musician named William Herschel.

Herschel's Work. — Herschel was a native of Hanover, where his father was a bandmaster in the Hanoverian Guards. From an early age he was attracted by science, and especially by the oldest of the sciences. But his father was by no means wealthy enough to permit his son to follow a scientific career. In 1755, therefore, young William Herschel entered the band of the Hanoverian Guards. In 1757 the Guard was ordered to fight against the French, who defeated the Germans at Hastenbeck. Herschel spent

the night after the battle in a ditch, where he had plenty of time to consider his future. After due consideration he decided to resign from the army—in other words, to desert. Having taken this step, he fled to England, where he soon established himself as a musician in Bath, but never lost his devotion to science. His sister Caroline came to keep his house for him, and in her autobiography she records the efforts of her brother to procure a telescope. He found that he could not afford to purchase an instrument, so he decided to make one for himself. Accordingly, he bought the apparatus of a Quaker optician, with which he commenced work. The form of telescope which Herschel decided to make for himself was the reflector, so called because it is formed on the principle of the reflection of light. One of the principal operations in making the reflector is the grinding and shaping of the mirror, and Caroline Herschel records that on one occasion her brother was obliged to hold his hands on the mirror for sixteen hours at a time. At length he succeeded in making a telescope with which he was enabled to observe the heavens. Once he had commenced observations, he went from discovery to discovery. Not only did he find a new planet, but he changed the entire course of astronomy by making possible the study of the stars, observed for their own sakes. The world had never seen so untiring an observer. For fifty years he and his sister worked in the cause of science. Herschel him-

self made the observations and dictated what he saw to his sister, who jotted down her brother's description. From this fifty years' untiring work of the German musician have sprung the greatest developments of modern astronomy.

Our Position in the Universe.—One of the great uses of astronomy is that it teaches us our position in the Universe. If we did not know anything about astronomy, we would not know of the Universe outside of our own Earth—we would not even know what to call our Earth; we would not know of its ceaseless motions through space or its endless rotation on its axis. Astronomy teaches us that our Earth is both a member of a system of bodies—the Solar System—and the centre of a little system of its own,—the Terrestrial System, or the Earth-Moon System as it has been variously called. We also know by means of astronomy that this collection of planets revolving round the Sun is merely one system out of many, and that as the Earth is merely a planet among other planets, so the Sun is only one star among other stars.

Practical Use of Astronomy.—But astronomy has another use besides giving us a proper idea of the Earth's place in Nature. The study of the stars has proved of the greatest practical use to mankind; for it is by its means that we measure time, and if we

had no proper measure of time, civilisation would be impossible. Our chief measures of time are—the day, the month, and the year. The first of these is the period of the rotation of the Earth on its axis; and although the day is, so to speak, ruled by the Sun, we do not measure the length of the day by noting the time taken for the Sun to complete an entire circuit. The Earth is moving round the Sun, and this causes an apparent displacement of the Sun; so we measure the day by the stars, and the time one star takes to move from the meridian to the same point again. These measurements have to be made by the most careful observations of the exact time at which a star crosses the meridian.

The late Professor Young, the well-known American astronomer, says: "It is by means of astronomy that the latitude and longitude of points upon the Earth's surface are determined, and by such determination alone is it possible to conduct extensive navigation. Moreover, all the operations of surveying upon a large scale, such as the determination of international boundaries, depend more or less upon astronomical observations. The same is true of all operations which, like the railway service, require an accurate knowledge and observance of the time; for our fundamental timekeeper is the daily revolution of the heavens, as determined by the astronomer's transit instrument." From this we see that without astronomy it would be impossible to conduct the

ordinary affairs of commerce. This is purely the practical side of astronomy. It is worth noting that by its bearing on the everyday affairs of life astronomy has received a good deal of public attention; and it is also worth noting that the Greenwich Observatory was founded primarily to assist navigation, which is indeed its main object even at the present day.

Educative Use.—Besides the two uses of astronomy already mentioned, there is another use—the educational value of the study of the stars. To again quote Professor Young: "The study of the science is of high value as an intellectual training. No other so operates to give us, on the one hand, just views of our real insignificance in the Universe of space, matter, and time, or to teach us, on the other hand, the dignity of the human intellect." By means of astronomy the imagination is touched, and by its aid we feel a sense of awe and wonder. Not only is astronomy a good mental training, but it is the powerful adjunct of religion; for in no other science do we see more plainly the hand of God in Nature. In the words of the Scottish astronomer, Thomas Dick: "To consider astronomy merely as a secular branch of knowledge which improves navigation and gives scope to the mathematician's skill, and to overlook the demonstrations it affords of the attributes of the invisible Divinity, would be to sink this noble

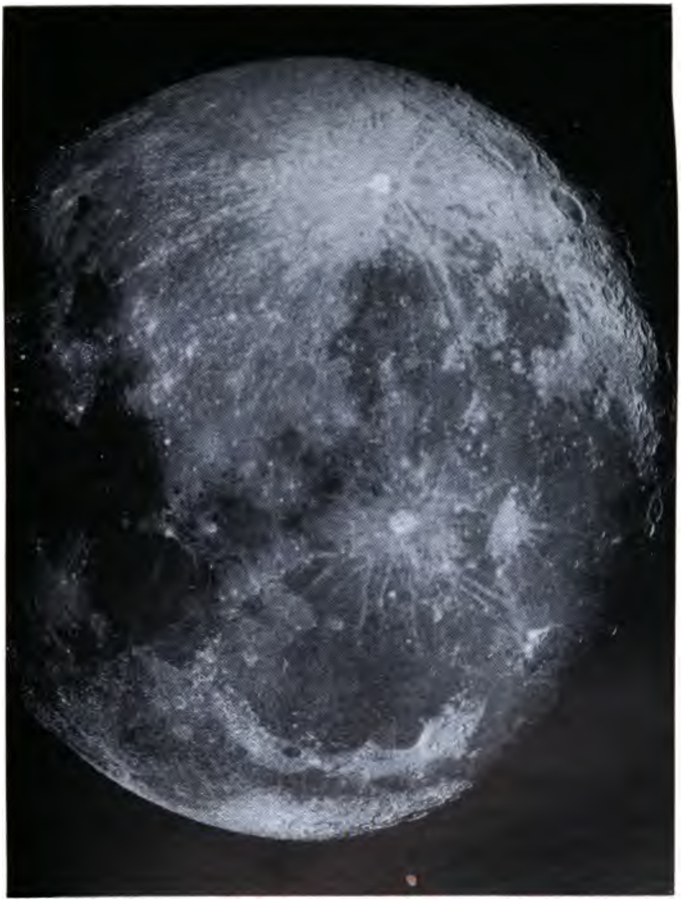
study far below its native dignity and to throw into the shade the most illustrious manifestations of the glories of the Eternal Mind." We read a great deal in the Bible of the infinite and the eternal. Astronomy leads our mind into these higher regions of thought and gives us practical illustrations of such phrases; for as Schiaparelli has so happily said, astronomy is the science of Infinity and Eternity.

CHAPTER II.

THE MOON.

In the olden days, as has been already said, it was believed that all the celestial bodies revolved round the Earth, and that our planet was the central body of the Universe. Now it has been proved that, with one solitary exception, there is not a single celestial body which owns allegiance to our planet: that solitary exception is our faithful satellite the Moon.

The Moon is comparatively close to the Earth. It is far removed from us when compared with our own terrestrial standards, but near when contrasted with the distance of the other celestial bodies. Its mean distance from the Earth is 238,000 miles, and its diameter is about 2160 miles, or, roughly, about a fourth of the diameter of its primary, the Earth. So near is the Moon that we now know its geography—or rather selenography—better than that of our own planet, and Flammarion refers to it as "a detached continent."



From a *Paris Photograph.*

THE MOON.

The pale beauty of our satellite, its ever-changing cycle of phases—from new Moon to first quarter, and on to full Moon and last quarter—have long secured for it a place in the interests of humanity. Its influence on the earthly landscape, and its power on the tides of the ocean, have long made it a favourite object to poets, and indeed to all thoughtful observers of Nature. Here is Flammarion's beautiful description of the rising of the full Moon: "It is the delightful hour when all Nature pauses in the tranquil calm of the silent night. The Sun has cast his farewell beams upon the weary Earth. All sound is hushed. And soon the stars will shine out one by one in the bosom of the sombre firmament. Opposite to the sunset in the east the full Moon rises slowly, as it were, calling our thoughts toward the mysteries of Eternity, while her limpid light spreads over space like a dew from Heaven."

Size of the Moon.—The Moon and the Sun were in olden days the most important of the celestial bodies, as indeed they are yet, so far as the Earth is concerned. Still, in proportion to the Moon's size as compared with the Sun, we are apt to overestimate our satellite. The Moon is the smallest celestial body which we can see without the aid of a telescope. The thousands of twinkling stars which we see at night, even the tens of millions revealed by the telescope, are each suns even grander than our own. The planets

are globes like the Earth, some very much larger, some smaller; but the Moon, which to us seems as large as the Sun, belongs to an inferior class of orbs altogether. It is merely the satellite of the Earth. The reason of the apparent large size of the Moon is that it is much nearer to us than the Sun or planets. We measure the Moon's distance in thousands of miles, the Sun's in millions.

To the Moon we owe the tides of the ocean. If the Moon were to be blotted out of existence entirely, the waters of the ocean would—with the exception of a small and insignificant tide raised by the Sun—at once grow stagnant. No waves would roll into the shores of our holiday resorts, for it is the attraction of the Moon which raises the tides on the ocean. The Sun does a little, but far too little for practical purposes.

When the telescope was first invented in 1610, Galileo turned it on the Moon and made several remarkable discoveries. He discovered that the Moon's surface was rugged and mountainous, and in addition he detected large grey patches, which he believed to be oceans on the Moon's surface. This view prevailed with his immediate successors, and when giving names to these patches they called them *Maria*, which is the Latin for seas. To this day there are on the Moon the Mare Tranquillitatis, or Sea of Tranquillity; the Mare Serenitatis, or Sea of Serenity, and other so-called seas. As a matter of

fact, they are not seas at all. Astronomers early ascertained that they were merely immense, comparatively level, grey plains, although increase in telescope power has shown that they are covered with minute mountains and volcanic craters. It is quite possible that they may be the dried-up beds of former oceans.

The Moon's Surface.—Thanks to the labours of a succession of able German astronomers—Tobias Mayer, Schröter, Lohrmann, Mädler, and Schmidt—we are now fully acquainted with the mountains and craters on the Moon's surface. There are many mountain-ranges, but the most prevalent type of formation is undoubtedly the volcanic crater. Even the smallest telescope will reveal the larger of these craters, such as the well-known formations called Plato, Tycho, and Copernicus. The late Mr Elger, a well-known English observer of the Moon, remarks: "However familiar we may be with the lunar surface, we can never gaze on these extraordinary formations, whether massed together in inextricable confusion or standing in isolated grandeur on the grey surface of the plains, without experiencing in a scarcely diminished degree the same sensation of wonder and admiration with which they were beheld for the first time."

These crater formations are grouped into various classes, which Elger gives as walled plains, mountain-

rings, ring-plains, craters, crater cones, craterlets, crater-pits, and depressions. Besides these there are the curious features known as "rills," long furrows in the lunar surface; and there are also the bright streaks which at the period of full Moon radiate from some of the larger craters, such as Tycho, Copernicus, and Kepler. No really satisfactory explanation of the cause of these streaks has yet been advanced.

Beer and Mädler, two German astronomers who devoted much attention to our satellite, commenced in 1830 an exhaustive trigonometrical survey of the Moon. They published the results of their studies in a large chart and a descriptive volume entitled 'Der Mond.' They came to the conclusion that the Moon was an absolutely dead world, and destitute of life of any kind, and this view has generally been adopted. It has been abundantly proved, too, that the Moon has no appreciable atmosphere; and the general idea among astronomers is that on such a world the existence of highly developed forms of life is exceedingly improbable.

Changes on the Moon.—Still there are indications that the Moon's surface is not absolutely changeless. In 1866 Schmidt announced that a well-known crater named Linné had lost all appearance of such; and in 1878 Klein of Cologne detected a new crater, which he supposed to have been newly

formed. In recent years Professor W. H. Pickering of Harvard, by the aid of photography, has detected a number of minute changes on the Moon's surface. He believes that there exists snow on the mountain-peaks and near the lunar poles, and that there is a form of vegetation in some of the craters; so it is possible that there does exist a thin lunar atmosphere, but far too thin to make the Moon in any way habitable by highly developed forms of life. If the Moon is not dead it is dying, and it rolls through space an extinct world, faithfully accompanying our Earth on its unending voyage round the Sun. That the Moon is now in a state of planetary old age is not to be wondered at, considering that it is a much smaller world than the Earth. Owing to its small size it must have cooled much more rapidly than the Earth, and run more swiftly through the stages of its existence.

Origin of the Moon.—It is now tolerably certain that at one time—probably millions of years ago—the Earth and Moon were not separate bodies. According to the exhaustive researches of Professor Darwin of Cambridge, at that time the Earth was a mass of incandescent gas, spinning on its axis in a very short period, between three and five hours. In consequence of this rapid rotation, and of the interference of the solar tide, the Earth split in two parts, and the smaller of these two parts now forms

the Moon, which gradually receded from us until it reached its present distance. The Earth, of course, continued to exercise a powerful influence on the Moon; and so powerful were the tides raised by our planet in the Moon's surface that the rotation of the Moon was retarded, and now our satellite requires to rotate on its axis, twenty-seven days,—the exact period which it takes to revolve round the Earth. The result of this coincidence between rotation and revolution is that the Moon always turns the same face towards the Earth. The consequence of this is that we have never seen the other side of the Moon. According to Professor Darwin, the Moon is now by its tidal action retarding the rotation of the Earth, and in the remote future the day of our planet will be fifty-five times its present length.

Eclipses.—We thus see how profoundly the Moon influences our planet and determines its future; but our satellite also influences us in another way. It is the principal agent in causing eclipses, from the observation of which astronomers have learned so much.

Eclipses are of two kinds—solar and lunar. The former are by far the most striking. The latter are merely a dimming of the light of the Moon. Every body shining by reflected light casts a shadow into space in a direction opposite to the source of illumination. Thus, the Moon casts a shadow, and the Earth casts a shadow. To us the Moon seems about the

same size as the Sun, and as both appear to move almost exactly in the plane of the ecliptic, it is quite reasonable to suppose that the nearer (the Moon) will sometimes pass over and hide from view the farther (the Sun). This occasionally does take place. Solar eclipses are subdivided into three classes—total, partial, and annular. A total eclipse takes place when the Moon is at its nearest point to the Earth, and appears large enough to hide the Sun. A partial eclipse occurs when the Moon is not exactly on a line with the Sun, and only covers a portion of the disc. An annular eclipse takes place when the Moon is at its farthest point from the Earth, and does not appear large enough to cover the disc of the Sun.

Lunar eclipses can be partial and total, but never annular. While an eclipse of the Sun lasts only a few minutes, a lunar eclipse may be several hours in length. Eclipses of the Moon are caused by the shadow of the Earth falling on the bright body of the Moon and cutting off its supply of light. Solar eclipses are caused by the shadow of the Moon falling on a part of the Earth's surface. It is well to bear in mind that solar eclipses can only occur at new Moon, and lunar eclipses at full Moon. Mr R. A. Gregory gives an instance of a novelist who, in one of his books, describes an eclipse of the Sun which took place at *full* Moon and lasted half an hour!

By means of solar eclipses, astronomers have been enabled to observe the regions in the vicinity of the

Sun which, but for the obscuration of the main body of the Sun, are lost in the solar glare. The solar corona and prominences, which will be dealt with in the chapter on the Sun, were first detected during eclipses; consequently, when a total eclipse of the Sun draws near, there is much activity in the astronomical world, and expeditions are fitted out to proceed to the regions crossed by the track of the eclipse. There has not been a total eclipse visible in the United Kingdom since 1715, when the eclipse of that year was observed by the famous astronomer Halley. All the valuable knowledge which springs from the observation of these eclipses is due to the two facts that the Moon revolves round the Earth in almost the same plane as the Earth's orbit, and that the Moon appears to us about the same size as the Sun. Eclipses of the Moon have been comparatively neglected by astronomers, because there is not the same store of information to be got out of them. The Moon, during eclipse, assumes a red, bronze, or copper colour, owing to the refraction of light from behind the Earth's atmosphere.

Total eclipses of the Sun have always been a source of terror to uncivilised nations. Even yet in China drums are beat and trumpets blown to frighten the "dragon" which is supposed to be devouring the Sun! The Hindus think that an eclipse causes food to be unclean, and consequently that it is unfit for use. In his 'Story of Eclipses,'

Mr G. F. Chambers gives an extract from an American newspaper showing the terror at eclipses among the Red Indians in the United States, recorded by an eye-witness of the eclipse of July 29, 1878. The Indians were terrified. "Some of them threw themselves upon their knees. Others flung themselves flat on the ground, face downward; others cried and yelled in frantic excitement and terror." At last an old Indian "stepped from the door of his lodge, pistol in hand, and, fixing his eyes on the darkened Sun, mumbled a few unintelligible words, and, raising his arm, took direct aim at the luminary, fired off his pistol, and after throwing his arms about his head, retreated to his own quarters. As it happened, that very instant was the conclusion of totality. The Indians beheld the glorious orb of day once more peep forth, and it was unanimously voted that the timely discharge of the pistol was the only thing that drove away the shadow and saved them from the public inconvenience that would have certainly resulted from the entire extinction of the Sun."

CHAPTER III.

THE SUN.

It is recorded that in ancient times some of the early peoples worshipped the Sun. They had an idea that all they had they owed to the great hot shining body which rose every morning and set every evening. They knew that it was the power of the Sun which caused life on the Earth, and to which they owed their own life and happiness. As Proctor remarks: "Of all the forms of religion in which created things were worshipped, Sun-worship was the least contemptible. Indeed, if there is any object which men can properly take as an emblem of the power and goodness of Almighty God, it is the Sun."

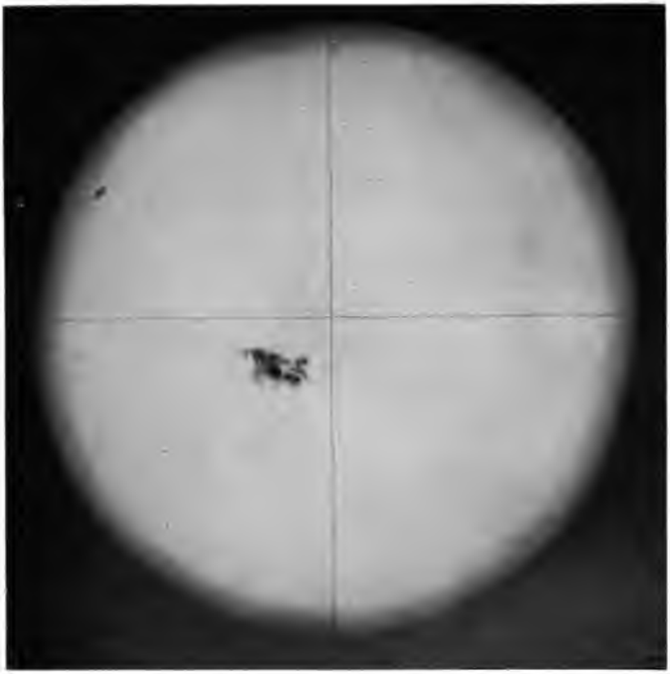
What we owe to the Sun.—The accuracy of these words of Proctor is borne out when we consider that the world could not exist a single day without the Sun, for the Sun is the source of all life on the Earth. Were it to be extinguished, this beautiful world of ours would be transformed into a

dead and frozen desert. The trees and flowers which make Nature so beautiful are due to the Sun's heat. It raises water from the seas and lakes, which falls as rain and refreshes the whole Earth; all our artificial light and heat, too, we owe to the Sun. Untold ages ago, great forests of trees grew and flourished by the heat of the Sun. In the course of ages these forests died and became embedded in the crust of the Earth, where they have become transformed into coal. Now miners go down into pits and bring the coal to the surface, and we use it to make the fires which bake our bread, guide our engines, and run our steamships. Indeed, everything we have we owe to the Sun, the beautiful as well as the useful. What is more beautiful than a summer's day? The green of the trees, the colours of the flowers, the flow of the rivers, the pure blue of a cloudless sky,—all go to make a summer's day a picture of beauty. What a difference there is between such a day and the dull days of winter, when clouds obscure from us the source of light and heat. It is difficult to realise that all the beauty which clothes our world comes from a great globe a million times larger than the Earth, situated at a distance of ninety-three million miles. That great globe is the majestic orb which we call the Sun.

Size of the Sun.—The diameter of the Sun is 866,000 miles; and so great is its volume that, sup-

posing all the planets, satellites, comets, and meteors of the Solar System were rolled into one globe, it would require 750 such globes to make one globe equal in volume to the Sun. It was not until early in the seventeenth century that there was any real knowledge of the physical condition of the Sun. In 1610 Galileo commenced observations, and detected on the solar disc a number of black spots. This was promptly disbelieved by the Roman Catholic priests, by most of the men of science of the day, and indeed by all opponents of the Copernican theory. Most astronomers believed the spots to be planets in transit, considering that the Sun could have no blemishes. Independently of Galileo, Christopher Scheiner, a German, and Johann Fabricius, a Dutchman, discovered the spots. Scheiner was a Jesuit priest of Ingolstadt, and on making the discovery went to acquaint the provincial Father of his order with what he had seen. The Superior priest, a zealous defender of the old ways of thinking, addressed him as follows: "I have read the whole of my 'Aristotle' several times, and I have found nothing similar there. Go, my son, quiet yourself, and be certain that there are defects in your glasses or in your eyes, which you take for spots on the Sun."

Theory of Sun-spots.—Observations of sun-spots were continued for many years before a rational



From a *Greenwich Photograph.*

THE SUN

theory of their nature was advanced. What is generally believed to be the true theory was put forward in 1769 by Alexander Wilson, Professor of Astronomy at Glasgow. By means of his observations Wilson showed that the spots were cavities in the Sun—depressions below the surface of the photosphere, or glowing face of the orb of day. Wilson's discovery was made the basis of Herschel's famous theory of the constitution of the Sun. Herschel regarded the Sun as a cool dark globe enveloped in a glowing atmosphere, and he believed the spots to be vast rents in this atmosphere through which a view of the cool dark solar globe was obtained. This theory held sway for many years, but it is now discarded. The spots are certainly rents in the glowing atmosphere; but the black and grey portions—the umbra and penumbra—are believed to be not absolutely dark, but merely dark in comparison with the photosphere.

Rotation of the Sun.—By means of the spots it was ascertained that the period of the Sun's rotation on its axis was about twenty-five days. Most of the spots last for at least one rotation before their dissolution, but some last for a longer period. Some of the spots are so gigantic that they could contain not only the Earth, but all the other planets of the Solar System as well. A German astronomer named Schwabe commenced in 1826 to observe the Sun daily. After thirty years' continual observation he

found that the number of spots was variable, and increased and decreased every eleven years. The period, however, is not quite constant, but fluctuates somewhat. Thus, 1878, 1889, and 1900 were years of few sun-spots, while 1882, 1893, and 1905 were years in which the disc of the Sun was covered with spots. Some time after this periodical fluctuation was discovered by Schwabe, two astronomers, Carrington and Spörer, independently discovered that the rotation of the Sun is performed in twenty-five days at the equator, and protracted to twenty-seven and a half days midway between the equator and the poles. Carrington also showed that sun-spots are scarce in the vicinity of the solar equator, but are confined to two zones on either side, becoming scarce again at thirty-five degrees north or south solar latitude.

The Spectroscope.—Most of our knowledge of the Sun has been gained, not with the telescope, but by means of the spectroscope, a remarkable and, indeed, marvellous instrument of astronomical research. It was shown by Sir Isaac Newton that if light is passed through a prism, it is dispersed into a band of coloured light similar to the rainbow in appearance. This band of coloured light, from the red to the violet, is known as the solar spectrum. In 1814, when Fraunhofer, a famous German astronomer and optician, was examining this spectrum, he discovered several dark lines crossing the band of coloured light.

He detected about three or four hundred of these lines, and gave names to the more prominent. He was at first much perplexed over the meaning of the lines. He found that they were conspicuous in the spectra of the Moon and planets, but not in the spectra of the stars. In other words, the lines were found to be characteristic of sunlight, whether direct or reflected, and sunlight only.

Kirchhoff's Laws.—But other kinds of light can be analysed besides sunlight. For instance, in a physical laboratory the lights of heated elements may be observed with the spectroscope. Each element, when analysed by the spectroscope, is characterised by one or more bright lines. Fraunhofer suspected that there might be some connection between these bright lines and the dark lines in the solar spectrum; but it was not till 1859 that the problem was solved by Kirchhoff, a German physicist. Kirchhoff showed that a gaseous substance gives a spectrum of bright lines, and a luminous solid or liquid a continuous spectrum. He also showed, as the late Miss Clerke explains, that "substances of every kind are opaque to the precise rays which they emit at the same temperature. That is to say, they stop the kinds of light or heat which they are then actually in a condition to radiate. . . . This principle is fundamental to solar chemistry. It gives the key to the hieroglyphics of the Fraunhofer lines. The

identical characters which are written bright in terrestrial spectra are written dark in the unrolled sheaf of sun-rays." The problem was now solved. All that astronomers had to do was to examine the spectra of heated elements, fix the position of the bright lines in these spectra, and then compare these determinations with the dark lines in the spectrum of the sun. By this method it was ascertained of what substances the Sun was composed; and Kirchhoff detected the presence in the Sun of such well-known elements as sodium, iron, magnesium, copper, and zinc.

Solar Prominences.—The spectroscope soon became a useful instrument in solar astronomy. For a long time it was observed that during a total eclipse of the Sun, red flames were seen at its edge while it was hidden by the Moon. These prominences, as they are called, have now been proved to be part of the Chromosphere, a sea of fire surrounding the Photosphere, from which flames of incandescent hydrogen are often hurled up to the height of three hundred thousand miles. Suppose the eight principal planets of the system—Jupiter, Saturn, Neptune, Uranus, the Earth, Venus, Mars, and Mercury—to be placed one on the top of the other beside these mountains of fire, the gigantic flame would still tower above them. After the total eclipse of 1868, it was discovered independently by Sir Norman Lockyer and

the late M. Janssen that the spectrum of these flames could be observed through the spectroscope, the flames being composed of hydrogen gas and showing a spectrum of bright lines. In 1869 Sir William Huggins and Dr Zöllner found that the forms of the prominences themselves could be observed by this method, and since 1869 the prominences, like the spots, have been more or less continuously kept under observation. In 1870 the late Professor Tacchini of Rome commenced to take daily observations of the prominences, and did for the study of these objects what Schwabe did for the spots. Tacchini found that the prominences increased and decreased every eleven years, just like the spots. These prominences, as already mentioned, originate in a shallow gaseous atmosphere termed the Chromosphere.

The Corona.—Outside the Chromosphere is the Corona, a silvery halo of light, only seen during total eclipses of the Sun. Little is known of its constitution; but its shape varies in sympathy with the eleven-year period of the spots and prominences. At the time of sun-spot maximum the Corona is distributed uniformly; at minimum, on the other hand, the polar regions of the Sun become devoid of coronal streamers.

Doppler's Principle.—One of the most remarkable uses of the spectroscope is the fact that by its means

motions may be measured. In 1842 Doppler, a German physicist, expressed the view that the colour of a luminous body would be changed by its motion of approach or recession, and that a larger number of light waves would be entering the eye of the observer if the body were approaching than if it were retreating. The late Miss Clerke thus illustrates Doppler's principle: "Suppose shots to be fired at a target at fixed intervals of time. If the marksman advances, say, twenty paces between each discharge of his rifle, it is evident that the shots will fall faster on the target than if he stood still; if, on the contrary, he retires by the same amount, they will strike at correspondingly longer intervals." In an approaching body the lines in the spectrum will be displaced towards one end of the spectrum; in a receding body towards the other. By this method several astronomers succeeded in noting cyclones and hurricanes in the Sun, and in measuring its rate of rotation. One astronomer, Dunér of Upsala, measured the Sun's rotation right up to the poles. He found that the rotation period at the poles is thirty-eight and a half days, while at the equator it is twenty-five days. In other words, the Sun does not rotate as a whole.

Solar Influences.—The Sun is the pulse of the Solar System. The eleven-year period, or solar cycle, not only affects the Sun, but influences also

the other planets. For instance, the magnetic variations on the Earth take place in a period of eleven years, and the aurora borealis also varies in sympathy with the sun-spots. Great magnetic storms and auroral displays usually take place when there is an important spot on the disc of the Sun. For instance, on February 9, 1907, a great auroral display was observed, and at the same time a large spot was visible on the solar disc. Mr Maunder, of Greenwich Observatory, finds that on the average magnetic storms are dependent on the presence of spots, and on the size of the spots. The magnetic action, he finds, does not radiate equally in all directions from the spots, but along definite and restricted lines.

Source of the Sun's Heat.—It has been calculated that if the Sun were composed of coal it would last for only six thousand years. Now, we know that the Sun has lasted for a much longer period, and that there are no signs of its decline. There must, therefore, be some mechanism by which the Sun's heat is maintained. It was suggested by the late Lord Kelvin that numbers of meteors falling into it might effect this purpose; but, as has been pointed out by Sir Robert Ball, supposing the Moon, for instance, were crushed into fragments and allowed to fall on the Sun's surface, the heat caused by these fragments would be exhausted in a year. Thus another theory must be formed. It has been found that the Sun is continually shrinking in

size, so that it actually contracts sixteen inches every day. By this contraction heat is generated which will keep the Sun at a high temperature for ten million years. After that it will become a cold, dark globe. An element of uncertainty, however, has been introduced into these calculations by the discovery of radium. In radium, it has been suggested, there may be another source of energy, which may alter the estimate. On this point, however, there is no unanimity of opinion. It is well to bear in mind that the inhabitants of this planet only receive a small fraction of the Sun's heat. Mr H. R. Mill, in his book 'The Realm of Nature,' gives the following admirable illustration of the Earth's share of the solar heat: "If the Sun were expending, instead of energy, money at the rate of £18,000,000,000 a-year, the Earth's annuity would only be £9."

Solar Constitution.—Many theories have been advanced of the exact constitution of the Sun, but none of them have survived. Professor Young of Princeton, New Jersey, one of the greatest authorities on the subject, in his 'Views on the Constitution of the Sun,' expresses the latest word of science on this point. According to Professor Young, "the photosphere is an envelope of clouds, formed by the condensation and combination of such of the solar vapours as are sufficiently cooled by their radiation into space. . . . The photospheric clouds are, of course, suspended in the surrounding gases and uncondensed

vapours, just as clouds float in our own atmosphere." The chromosphere consists of "simply the uncondensed vapours and gases which form the atmosphere in which the clouds of the photosphere are suspended."

It is difficult to conceive the enormous forces which are at work in the solar globe. As one able writer has said: "A mighty conflict goes on unceasingly between imprisoned and expanding gases and vapours struggling to burst out, and massive pressures holding them down. For reasons which we cannot fully understand, no equilibrium is reached. For millions of years up-rushes and down-rushes of the white-hot materials have been proceeding on that bright photosphere which gives us light and looks a picture of calm and quiescence. Above that is a comparatively thin rose-coloured layer, agitated with fiery prominences, and outside all these the coronal glory—all alike pointing to immeasurable activities."

CHAPTER IV.

THE INNER PLANETS.

THE Sun, as we have seen, is the centre of a system of bodies of various sizes, situated at various distances, and all of which are in constant revolution round their primary. These bodies, of which the Earth is one, are known as the planets. The word "planet" is Greek for "a wandering star," and was given to these bodies by the ancient Greeks because, unlike the stars, they did not remain in the same fixed position in the sky, but travelled through the Zodiacal constellations.

Groups of Planets.—The planets are divided into three well-defined groups, which are: (1) The inner planets, consisting of Mercury, Venus, the Earth, and Mars; (2) the outer planets, Jupiter, Saturn, Uranus, and Neptune; and (3) the Asteroids or minor planets, a group of about seven hundred very small orbs situated between the orbits of Mars and Jupiter. There are four known members of the inner group and four

of the outer; but at one time it was thought that the inner group contained five planets—that a planetary body existed between Mercury and the Sun. In the middle of last century, Le Verrier, the great French astronomer, came to the conclusion that Mercury was being attracted by some unknown body or bodies, and he announced that probably another planet existed within the orbit of Mercury. Mercury is very difficult to see, as it is so close to the Sun, and if a planet existed at only half the distance, it would be utterly invisible, except when in transit, or during a total eclipse, when the Sun's light is obscured for several minutes. Thus the difficulties in the way of observing a planet between Mercury and the Sun are very great. Soon after Le Verrier's statement, however, a remarkable observation was made. In 1859 Dr Lescarbault, a Frenchman, announced that he had seen a planet in transit across the disc of the Sun, and Le Verrier believed that the disturber of Mercury had been discovered. He named the object "Vulcan," and announced that it revolved round the Sun in twenty days. Le Verrier predicted that Vulcan would be seen in transit on March 22, 1877, and October 15, 1882. But on those days, though an exhaustive search was kept up, no trace of a planet could be seen. In 1876, a German named Weber announced that he had found the long-looked-for Vulcan, but after some inquiry it was found to be a sun-spot without penumbra.

In 1878 Watson, the American astronomer, stated that in that year, during the total eclipse of July 29, he had seen Vulcan shining south-west of the eclipsed Sun, showing a small disc. The same observer also thought he saw another planet. Another astronomer, Professor Swift, considered that he could see two different planets from Watson's. But these planets were certainly not the "Vulcan" observed by Lescarbault, which ought to have then shone, according to calculations, to the east side of the Sun. Since then nothing has been seen which has been suspected to be Vulcan, and belief in its existence has died out.

Mercury. — Mercury, the nearest of the known planets to the Sun, is very difficult to observe. In his poetic language Flammarion says: "A little above the Sun one sometimes sees, now in the west, in the lingering shimmer of the twilight, now in the east, when the tender roseate dawn announces the advent of a clear day, a small star of the first magnitude which remains but a very short time above the horizon and then plunges back into the flaming Sun." In the British Islands, and particularly in Scotland, Mercury is not easy to detect. Indeed, in the whole of northern Europe it is difficult of observation, and it is recorded that Copernicus, who spent his life in Poland, died without ever seeing the planet. Notwithstanding this difficulty, astronomers have ascertained that it is a globe of about 3030 miles in

diameter, and that it is distant on the average 36 millions of miles from the Sun, round which it revolves in eighty-eight of our terrestrial days. It is much smaller than our planet, and it would require twenty-five globes of its size to make one Earth.

Mercury shows phases similar to those of the Moon, and these phases may be observed with the aid of a telescope. But telescopic observations of both Mercury and Venus are undertaken with considerable difficulty. When Mercury and Venus are at their nearest, their dark sides are presented towards us. When they are on the other side of the Sun, or "full," they are lost in the rays of the great luminary. Consequently we can never observe the planets fully illuminated.

Rotation of Mercury.—The question of the rotation of Mercury has long been debated. The German astronomer Schröter considered that the period of rotation was 24 hours 5 minutes; but this has been practically disproved by Schiaparelli of Milan. In 1882 that distinguished astronomer commenced a series of observations on Mercury, observing the planet in the day-time, and in 1889 he announced that the period of rotation is eighty-eight days—equal to the period of revolution. This means that the planet turns the same face continually towards the Sun as the Moon does to the Earth, and that one side of the planet is in perpetual daylight and the other

Rotation Period.—In the seventeenth century Cassini concluded that the rotation of Venus was performed in a short period—about twenty-three hours. Belief in a short period was retained until 1890, when Schiaparelli announced that Venus, like Mercury, performed only one rotation on its axis during its period of revolution. Schiaparelli's conclusion in the case of Venus is not so certain as in that of Mercury, but on the whole it is generally accepted. It is satisfactorily explained by Darwin's theory of the tides, which shows that the solar tides on both Mercury and Venus retarded the periods of their rotation. Venus and Mercury have no satellites, and Darwin points out that this is quite natural, as the solar tide would certainly prevent the formation of satellites.

Physical Condition of Venus.—Little is known of the physical condition of Venus. It is believed by some astronomers that the surface of the planet is very rugged and mountainous, while others think that we do not see the true surface at all, but only a thick canopy of clouds. Sir Robert Ball remarks that even though the long-rotation period is correct, "we might expect to find in that planet a luxuriant tropical life, of a kind perhaps analogous to life on the Earth."

If there are inhabitants of Venus, and if they can see the outer Universe at all, their eyes will be

gladdened by a beautiful celestial spectacle such as we on this planet are not privileged to see. A beautiful star shines to the inhabitants of Venus far more brightly than Venus does to us, and without the aid of a telescope the star, which at a first glance will appear as a blaze of light, will be seen in reality to consist of two stars, the smaller revolving round the larger. These stars are none other than our own Earth and its satellite the Moon.

Transits. — Venus and Mercury, being situated within the orbit of the Earth, sometimes pass between the Sun and the Earth, and appear as black spots on the Sun's disc. Such occurrences are called transits. The first observed transit of Venus was predicted by Kepler for 1631. These transits occur in pairs, separated by eight years, and the pairs are separated by intervals of 105½ and 121½ years. Kepler, although he predicted the transit of Venus of 1631, did not know that they occurred in pairs, and did not expect another till 1761. A young Englishman named Horrocks, however, began to make calculations which led him to the conclusion that Kepler had overlooked the fact that the transits occur in pairs, and predicted a transit of Venus for 1639. His prediction was fulfilled.

The next pair of transits occurred in 1761 and 1769. Some time before this, however, Halley had remarked that observations on Venus while in transit would

lead to a correct measurement of the distance of the Sun. Several expeditions of astronomers were sent out to different ends of the Earth to make observations. From the results of the transits of 1761 and 1769 Encke concluded that the Sun's distance was 95 millions of miles. The next two transits took place in 1874 and 1882, and for long they were eagerly looked forward to by astronomers, in order to measure the Sun's distance exactly. The results were, however, disappointing. The next pair of transits will take place in 2004 and 2012, and there will be other two in 2117 and 2125. Transits of Mercury are not of so much interest as those of Venus, and they are not nearly so rare. There was a transit of Mercury in 1631, predicted by Kepler. The last took place in 1907, and there will be another in 1917.

Mars. — According to the figures given in Mr Peck's 'Atlas of the Heavens,' the diameter of Mars measures 4230 miles. The planet is situated at a distance of 140 millions of miles from the Sun, round which it revolves in a period of about 687 days. Mars rotates on its axis in a period of 24 hours 37 minutes 22 seconds, its day being only half an hour longer than our own; and, according to Mr Lowell, the axis is inclined 25 degrees to the plane of the planet's orbit, so that the seasons are somewhat similar to ours.

The poles of Mars are distinguished by two white spots, which increase and decrease periodically, first discovered in 1719 by Maraldi, the nephew of Cassini. They were attentively observed by Herschel, who concluded that they were composed of snow and ice. Since then many eminent observers have studied the polar caps. In 1830 Beer and Mädler observed surrounding the north polar cap a broad blue belt. In 1894 the south polar cap was attentively observed by Mr Lowell at the Lowell Observatory, Flagstaff, Arizona. On June 3, 1894, the cap was 2035 miles across. As it melted, Mr Lowell observed a broad blue belt surrounding it, similar to that seen by Beer and Mädler in 1830. On October 13 the polar cap completely vanished. This was the first time since astronomers began to observe the planet that the cap was observed to disappear.

The climate of Mars is probably colder than ours, owing to the planet's greater distance from the Sun. The equatorial regions probably correspond to our temperate zones. The atmosphere of Mars is much more rarefied than that of the Earth, and is generally cloudless; and, according to Mr Lowell, it is thinner at least by half than the air of the summit of the Himalayas. Of the Martian atmosphere Miss Clerke says: "This slender envelope is exceedingly extensive. In the pure sky, scarcely veiled by it, the Sun, diminished to less than half his size at our horizons, probably exhibits his coronal streamers as a regular part

of his noontide glory; atmospheric circulation proceeds so tranquilly as not to trouble the repose of a land 'in which it seemeth always afternoon.'"

Surface of Mars.—It was early observed that the surface of Mars was distinguished by red and green markings, which were generally believed to represent continents and oceans. Numerous astronomers of note observed the planet before 1877, among them Mädler, Lockyer, Proctor, Dawes, Schmidt, Secchi, Flammarion. Dawes and Secchi had indeed observed one or two of the more conspicuous canals, but failed rightly to interpret the observations.

Canals of Mars.—In September 1877 Professor Schiaparelli, the director of the Brera Observatory in Milan, discovered that the "continents" or red portions of the disc were cut up by numerous dark lines, to which he gave the name of *canali.* Astronomers, however, were inclined to be sceptical regarding the reality of the discovery. All the same, Schiaparelli continued his observations. In the end of 1879 he discovered that one of the canals had become double—that is, a new canal ran parallel to the original one, a discovery which he fully confirmed in 1881, when no less than twenty canals became double. In the following oppositions Professor Schiaparelli confirmed what he had seen previously, and in 1888 he declared that the canals had all the distinctness of an engraving on

From Drawings by Professor Lowell.

MARS.

steel, with the magical beauty of a coloured painting. Two years later, owing to imperfect eyesight, he discontinued his observations on Mars.

In 1886 M. Perrotin of the Nice Observatory recognised the double and single canals drawn by Schiaparelli. In 1892 an extensive series of observations was made by Professor W. H. Pickering at Arequipa, Peru. At the junctions of the canals he discovered dark spots which he called lakes, in keeping with the view then prevalent that the seas were really bodies of water. Two years later Professor Pickering observed the so-called seas with the polariscope, and showed that they were probably not aqueous.

At the Lowell Observatory in 1894 Mr Lowell and his assistant, Mr Douglass, made an extensive series of valuable observations. Altogether Mr Lowell mapped 350 canals, double and single. Mr Douglass also detected in the dark regions of the planet what Professor Schiaparelli observed in the light. The canal system was thus proved to extend all over the planet. Professor Lowell has since continued his observations at each opposition. In 1903 he made a series of observations which showed a systematic distribution of the double canals. In May 1905 he succeeded in securing a few photographs of the canals, and at the more favourable opposition of 1907 he succeeded in photographing both the single and double canals, so that the latter must be real objective phenomena.

What are the canals? Many theories have been advanced. Proctor regarded them as rivers, while other astronomers suggested that they might be cracks in the surface or chains of mountains running over land and sea. The canals are regarded by Schiaparelli as waterways lined on either side by banks of vegetation; and this forms the basis of the exhaustive theory of Professor Lowell, which was first propounded in 1895 in his book 'Mars,' and further developed in 1906 in a second volume on the red planet. Professor Lowell is of opinion that the reddish-ochre regions or "continents" are deserts, and the greenish areas marshy tracts of vegetation. The lakes are named by him "oases," and, as Miss Clerke observes, he "does not shrink from the full implication of the term." He regards the canals as strips of vegetation fertilised by a small canal, much too small to be seen,—an idea which originated with Professor W. H. Pickering. The canals are believed by Mr Lowell to be waterways down which the water from the melting polar cap is conveyed to the various oases. He considers, in fact, that the canals are constructed by intelligent beings with the express purpose of fertilising the oases regarded by him as centres of population. He remarks that water is scarce on the planet owing to its small size, and as a consequence the inhabitants are forced to utilise every drop. The canal system is the result. The theory, at first ridiculed, is gradually gaining ground.

Still another theory must be mentioned, which is supported by Signor Cerulli, an Italian astronomer, Professor Newcomb, Mr Maunder, and M. Antoniadi. This is known as the "optical illusion" theory. Professor Newcomb says of the canaliform appearance: "This phenomenon is not to be regarded as a pure illusion on the one hand or an exact representation of objects on the other. It grows out of the spontaneous action of the eye in shaping slight and irregular combinations of light and shade, too minute to be separately made out into regular forms." This view has been extended by Mr Maunder and M. Antoniadi, but it received a severe blow when Professor Lowell succeeded in photographing the canals. Meantime Professor Lowell's theory undoubtedly holds the field.

Mars, then, if Mr Lowell's hypothesis be correct, is an inhabited world. Theoretical considerations lead us to the belief that if there ever were inhabitants of Mars they should now be suffering from scarcity of water. Therefore, if in an advanced state of civilisation, they would probably construct a network of canals similar to what we actually observe. When, therefore, we see canals where from theoretical consideration canals ought to be, it cannot be denied that there is much to be said in favour of the idea that Mars is inhabited by a race of beings who, as Mr Lowell says, "are in advance of, not behind, us in the journey of life."

Satellites of Mars.—For many years it was believed that Mars, like Venus and Mercury, was devoid of satellites, and Tennyson in one of his early poems refers to "the snowy poles of moonless Mars." At length, however, in August 1877, two minute satellites were discovered by the late Professor Asaph Hall with the great 26-inch telescope at Washington. To these moons Professor Hall gave the names of Phobos and Deimos. He determined the time of revolution of Phobos at 7 hours 39 minutes, and that of Deimos at 30 hours 17 minutes. Thus Phobos revolves round Mars more than three times in a Martian day. As the satellite moves more swiftly than the planet rotates, it will appear, from the surface of Mars, to rise in the west and set in the east. Both satellites are very close to Mars, the distance of Phobos from the centre of the planet being 5800 miles and that of Deimos 14,500 miles.

In the clear Martian sky the Earth will appear as a bright and beautiful star accompanied by a smaller and fainter orb—the Moon. In the words of Flammarion, "We are for Mars a brilliant star, presenting an aspect similar to that which Venus presents to us, preceding the dawn and following the twilight; in a word, we are to the inhabitants of Mars 'the shepherd's star.' Our natural vanity might then delude us with the idea that the inhabitants of Mars contemplate us in their evening

sky purpled with the last solar rays; that they admire us from afar; that they have discovered our phases and those of the Moon, as we have discovered those of Venus and Mercury; and that they suppose our world to be a celestial abode of peace and happiness. Perhaps, even, they raise altars to us. What a disillusion if they could observe us a little nearer!"

CHAPTER V.

THE OUTER PLANETS.

The Asteroids.—About three hundred years ago Kepler pointed out that between the orbits of Mars and Jupiter there was space for another planet to revolve, invisible on account of its small size. His ideas were not treated seriously, but in 1772 a famous German astronomer, Bode, took up the subject again. He investigated a curious relationship, now known as "Bode's Law," existing between the distances of the planets from the Sun. If four is added to each of the numbers—0, 3, 6, 12, 24, 48, 96, and 192, the series becomes 4, 7, 10, 16, 28, 52, 100, and 196. Now, these numbers represent the distances of the planets thus—4 (Mercury), 7 (Venus), 10 (the Earth), 16 (Mars), 52 (Jupiter), and 100 (Saturn). After the discovery of Uranus in 1781 it was found that it filled up the number 196 (Neptune was then unknown). Bode, however, saw that the number 28, between Mars and Jupiter, was vacant.

He predicted that a planet would be found; and in 1800 astronomers were so certain that such a planet existed that a number of them assembled at Schröter's Observatory at Lilienthal, near Bremen, with Von Zach as president, for the purpose of finding the missing planet. The Zodiac was divided into twenty-four zones, each zone given to a separate astronomer.

Discovery of Ceres.—Piazzi, director of the observatory of Palermo, in Sicily, was ignorant of the fact that he was included in the "celestial police," as the planet-searchers had been termed by Von Zach. On January 1, 1801, the first night of the nineteenth century, he observed a telescopic star of the eighth magnitude in the constellation of Taurus. The next few nights showed that the object was moving; but Piazzi never suspected that he had found a planet, thinking that what he had discovered was a tailless comet. He wrote, however, to Bode, who at once came to the conclusion that the missing planet had been found. Piazzi watched the object till February 14, when he was taken ill. There were not enough observations for an orbit to be calculated for the planet, and before Piazzi could resume observations the object was lost in the rays of the Sun. A young mathematical astronomer—the famous Gauss—had, however, recently discovered a method whereby a planetary orbit could be calcu-

lated with very few observations. Gauss calculated the orbit of the newly found planet. He advised astronomers where to look for it, and it was rediscovered on December 31, 1801, by Von Zach at Gotha. By Piazzi's request the little planet received the name of Ceres.

On March 28, 1802, Olbers, at Bremen, when observing Ceres, saw a strange object near the path of the new planet. In a few hours it was proved that it was in motion, and was therefore another planet. It was named Pallas. Olbers was so impressed with the similarity of the orbits of Ceres and Pallas, that he suggested that they might be pieces of a planet which had, through some catastrophe, been destroyed. Olbers also predicted that more little planets would be found, and kept up a search for them. On September 2, 1804, Harding, Schröter's assistant, found another planet, which was named Juno, and on March 29, 1807, Olbers himself discovered Vesta.

Thirty-eight years elapsed before any further discoveries were made. The four little planets were named by William Herschel "the Asteroids," and before a fifth was found, Piazzi, Harding, and Olbers were dead. In 1845, however, Hencke, a German amateur, discovered Astræa, and in 1847 Hebe. Since 1847 several, and in many cases as many as twenty, planets have been found annually, and the number of asteroids now almost reaches 700. The asteroids were

termed by Sir John Herschel in his 'Astronomy' the "Ultra-Zodaical planets," from the circumstance that their orbits are considerably inclined to the plane of the ecliptic, and therefore do not appear to move in the narrow belt called the Zodiac. The asteroids have also been named the "Planetoids" and "Minor Planets." "Minor Planets" and "Asteroids" are the names now in general use.

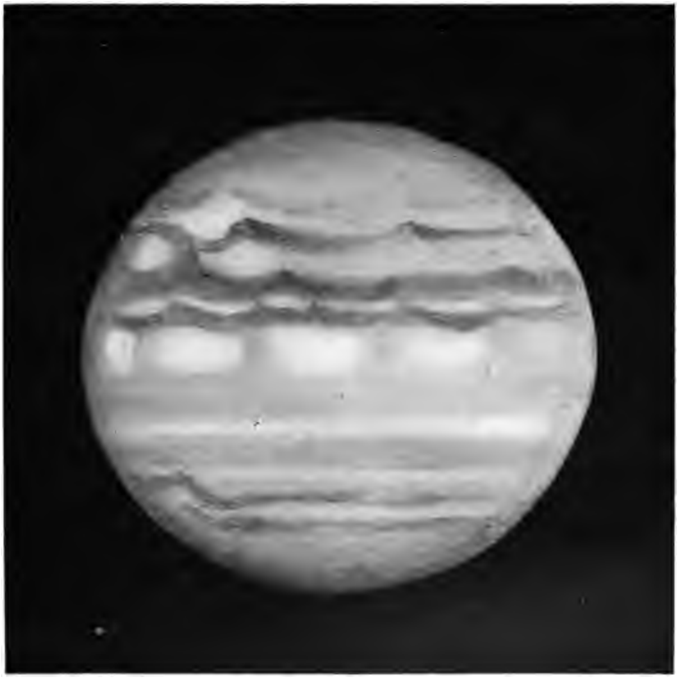
The asteroids revolve round the Sun in very elliptical orbits, and, as has been said, do not, like the other planets, move almost exactly in the plane of the ecliptic. The orbit of Pallas, which is the most extreme, is inclined no less than thirty-four degrees to the ecliptic. The little planets show great differences in the time they require to revolve round the Sun, varying from three to nine years. While some of them go very close to Jupiter, one, Eros, discovered in 1898, can actually come closer to the Earth than Mars. All the larger and brighter asteroids have probably been found. Indeed, in recent years the custom has been for astronomers to expose a photographic plate to certain parts of the heavens, and on examining it to see if any "planetary trail" caused by the movement of the asteroid can be detected. If so, the observer gains the honour of having discovered a new asteroid. Dr Max Wolf of Heidelberg has discovered more than one hundred asteroids by this method, of which he was the originator; and by means of a recent invention, the stereo-comparator,

an instrument on the lines of the old stereoscopes, he has detected many more.

Size of Asteroids.—The brightest of the asteroids is Vesta, which for long was supposed to be the largest. But with the great Lick telescope Professor Barnard in 1895 secured the first really accurate measures of their diameters.

The earliest discovered asteroids are the largest. Professor Barnard's measures show that Ceres is 477 miles in diameter, Pallas 304 miles, Vesta 239 miles, and Juno 120 miles. Vesta must therefore have a large "albedo" or reflective power, reflecting more light than Ceres, though inferior to it in size. The remainder of the asteroids are so small that they do not show discs, and therefore cannot be measured. Hornstein, a German astronomer, considers that those having a greater diameter than twenty-five geographical miles are few in number. On some of the smaller asteroids gravitation is so weak that a ball flung up with an ordinary velocity would leave the planet for ever.

Jupiter.—Beyond the orbits of the asteroids is situated the pathway of Jupiter, the largest planet in the Solar System. The diameter of Jupiter measures 92,164 miles, and an idea of its vast size may be gained from the fact that it is greater than all the other planets put together. Jupiter travels



From a Drawing *by the Rev. James Baikie.*

JUPITER.

at the rate of eight miles a second, and is situated at a mean distance of 484 millions of miles from the Sun, round which it revolves in 4332 days, or nearly twelve of our terrestrial years.

Satellites of Jupiter.—Jupiter appears to advantage in a small telescope, showing a full round disc of large size; and one of the first-fruits of telescopic discovery was in connection with the giant planet. In January 1610 the famous Galileo turned his telescope on Jupiter, and noted three stars near to the disc. Great was his surprise next evening to find that not only Jupiter, but the three stars as well, had moved. He at once suspected that they revolved round Jupiter, as the Moon revolves round the Earth, and a few nights later, when a fourth satellite was discovered, Galileo proved that these satellites revolved round Jupiter. This discovery was a great triumph for the believers of the Copernican theory. Copernicus had said that the planets revolved round the Sun, but there was nothing to show that such a state of affairs existed elsewhere. By the discovery of the satellites of Jupiter, Galileo had found that the little worlds revolved round the planet as the planets of the Solar System revolve round the Sun, and there through his telescope he saw a beautiful miniature of the Solar System. Still the opponents of the Copernican theory would not believe in the satellites. One astronomer declared that

the satellites, being of no use to the Earth, could not and did not exist; others refused to look through the telescope in case they would see the satellites and have to believe in them; while others who had looked through and had seen them, said that only certain telescopes would show them, as they were in the telescope and not in the sky. The satellites of Jupiter are sometimes known as Io, Europa, Ganymede, and Callisto.

The system of Jupiter, after an interval of over 280 years, has again been considerably enlarged recently. On the 9th of September 1892, Professor Barnard of the Lick Observatory, California, was observing Jupiter with what was then the largest refractor in the world, when he saw a minute point of light near the planet and moving along with it. He suspected it to be a fifth satellite, and the next night his suspicions proved correct. This fifth satellite revolves round the planet at a distance of 112,000 miles. From the same observatory early in 1905, the discovery of other two new satellites was announced. The new sixth and seventh satellites, which were discovered by Professor Perrine by means of photography, were found to be situated at a considerable distance from the planet, the periods of revolution being 242 days and 200 days respectively. Early in 1908 an eighth satellite, at a still greater distance, was discovered at Greenwich by means of photography. Its motion is retrograde.

Belts of Jupiter.—The satellites of Jupiter were Galileo's only discoveries in connection with the planet. His telescope was not powerful enough to show the markings on Jupiter's disc. After the time of Galileo, astronomers with more powerful telescopes discovered that the surface of the planet was distinguished by long markings known as belts, which always run parallel to the equator. These belts are now known to be huge masses of cloud. They are usually reddish in colour, extend for thousands of miles, and are often marked with spots. In his interesting work 'Pleasures of the Telescope,' Mr Garret P. Serviss gives the following striking description of these cloud-belts: "Belts of reddish cloud many thousands of miles across are stretched along on each side of the equator of the great planet. . . . The equatorial belt itself, brilliantly lemon-hued or sometimes ruddy, is diversified with white globular and balloon-shaped masses which almost recall the appearance of summer cloud domes hanging over a terrestrial landscape; while toward the poles shadowy expanses of gradually deepening blue or blue-grey suggest the comparative coolness of these regions which lie always under a low sun."

The markings on Jupiter are not like those on the Moon or on Mars, but are continually changing like the spots on the Sun. Some features, however, have a degree of permanence. An object on Jupiter

known as the "great red spot" was first observed by M. Niesten of Brussels in 1878, and is still visible. It grew steadily fainter for some time after its discovery, and astronomers thought it was going to disappear altogether, but it brightened up again and is still to be seen.

By observations on the belts it has been found that Jupiter rotates on its axis in 9 hours 55 minutes. The result of such a rapid rotation—the swiftest known in the Solar System—is that the planet is very much flattened at the poles, the equatorial diameter exceeding the polar diameter by eight thousand miles. By observations on the belts, too, astronomers have reached conclusions concerning the present condition of the planet. It was formerly supposed that the belts of Jupiter were analogous to the trade-winds on the Earth; but in 1865 the German astronomer Zöllner pointed out that they could not be due to sun-heat alone, as Jupiter's atmosphere is far more cloudy than our own, and yet the great planet is at a much greater distance from the Sun than the Earth. These belts are raised by heat,—not by the heat of the Sun, but by the heat of the planet itself. Jupiter is 1300 times larger than the Earth, and it is quite natural that it should be in so heated a condition that the water which on the Earth takes the form of oceans is on Jupiter kept above the surface as vapour. Another fact makes the theory very probable. Though Jupiter is 1300 times as large as the

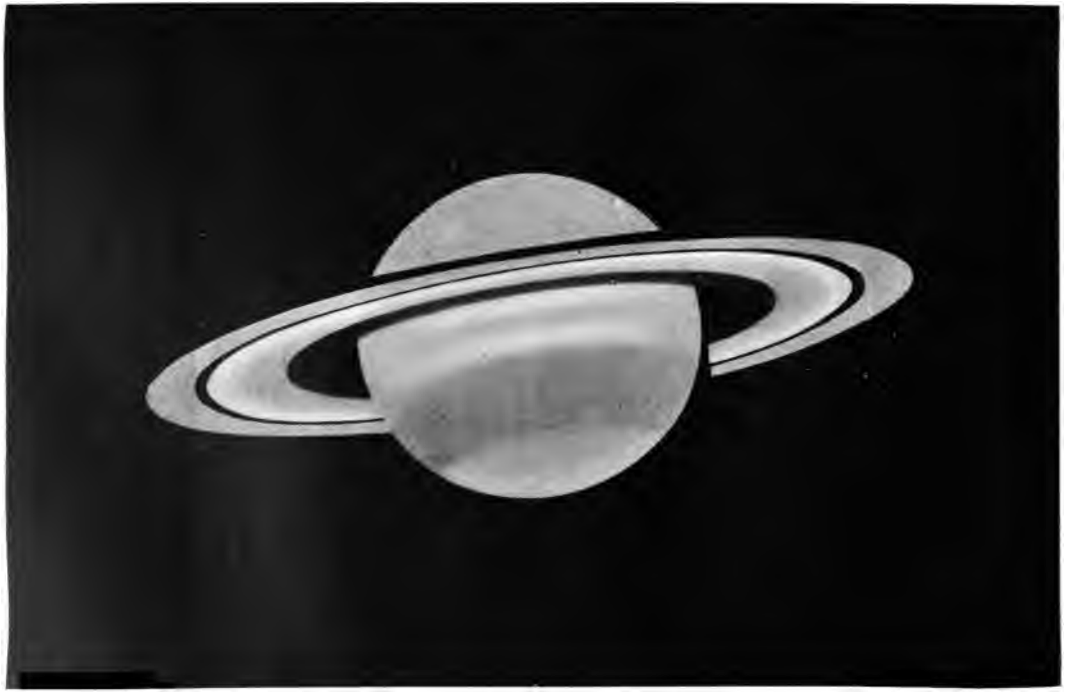
Earth, it is only 300 times as heavy, and the lightness of the planet can only be explained by supposing that it has not yet parted with its heat. In fact, Jupiter is practically a miniature sun. It is not nearly so hot as the Sun, and does not shine by its own light, but it is still far too hot to be inhabited. It is in much the same condition as our own planet was ages ago, at that far-away epoch when "the Earth was without form, and void, and darkness was upon the face of the deep."

Saturn.—Revolving round the Sun at a mean distance of nearly 900 millions of miles in a period of thirty years is the gigantic Saturn, the second largest of the planets, only surpassed in size by Jupiter. Saturn's mean diameter is about 74,000 miles. In size it is to the Earth as a small orange is to a pea. As a star Saturn presents no peculiar appearance. It is not nearly so bright as Venus, Jupiter, or Mars; it is even surpassed by the brighter of the stars proper. This is due to two causes: first, Saturn, being so much farther from the Sun than Jupiter, is much less brightly illuminated; and secondly, it is situated at almost double the distance of Jupiter from us, and must appear insignificant. When the telescope is turned on Saturn, however, we behold a glorious orb. It is surrounded by three beautiful rings; its disc is striped with belts similar to, though fainter than, those on Jupiter; and ten

little points of light circle round the planet, guided by its powerful attraction.

Rings of Saturn.—Galileo, having been so successful in observing the other planets, turned his telescope on Saturn. Here he beheld something completely different from the other planets of the Solar System. Galileo's telescope was not powerful enough to show the rings, and the planet appeared elliptical or oval-shaped, similar to the appearance that would be presented by a large planet with two smaller globes on each side. Galileo accordingly announced that the planet was composed of three globes. It was not long, however, before the great Italian astronomer found that this explanation was incorrect. In 1612, what Galileo took for two smaller planets decreased in size and eventually disappeared. He was so disappointed with his result that he ceased observing Saturn altogether.

After the time of Galileo many astronomers tried to solve the Saturnian mystery. Some suggested that the elliptical shape might be caused by two handles attached to the planet; others thought that it might represent the remains of a comet which had come too near to Saturn and had got twisted round the planet; but it was not until 1656 that the true nature of the rings was disclosed. The famous Dutch astronomer Huyghens, having observed Saturn with much more powerful telescopes than



From a Drawing *by Professor Barnard.*

SATURN.

those used by Galileo, came to the conclusion that the appearances could only be explained by supposing that the planet was surrounded by a ring. He wished to test his theory in every way possible, so that there could be no chance of a mistake. But this would cause long delay, and, for all that Huyghens knew, some other astronomer might make the discovery independently. Accordingly, Huyghens, in order to secure the rights of discovery, published a curious mixture of letters as follows: "a a a a a a a c c c c d e e e e e g h i i i i i i i l l l l m m n n n n n n n n n o o o o p p q r r s t t t t t u u u u u." After waiting three years to prove the truth of his discovery, he in 1659 arranged the letters into their natural order, making up the following Latin sentence: "Annulo cingitur, tenui, plano, nusquam cohaerente ad eclipticum inclinato," which, translated, reads, "The planet is surrounded by a slender flat ring inclined to the ecliptic, but which nowhere touches the body of the planet." Huyghens also predicted that in 1671 the ring would become invisible, as it did in the time of Galileo. At first his discovery was ridiculed, but when Cassini, in the year predicted, saw Saturn as a round globe with no trace of a ring, Huyghens' explanation was accepted. In 1675 Cassini found that the single ring discovered by Huyghens was in reality composed of two rings. These two rings were all that were known until 1850, when it was observed independently by Bond, an American, and Dawes, an

English astronomer, that Saturn had yet another ring, much fainter than the rest. It is called the "dusky" ring, and is so transparent that the globe of the planet can be seen through it.

Of what are the rings composed? For a long time this was a difficult question. They were considered by Laplace and Herschel to be solid, and when it was proved that no solid rings could exist without crashing down on the planet, it was suggested that they might be fluid; but in 1857 Professor Clerk-Maxwell proved that they were neither fluid nor solid, but must be composed of millions of meteors revolving round the planet, so numerous as to appear as a solid whole. In 1895 this theory was confirmed by observation by the late Professor Keeler, director of the Lick Observatory. Professor Keeler examined Saturn with the spectroscope, and by means of Doppler's principle it was found that the inner edge of the ring rotated in about seven hours, and the outer edge in ten hours. Now, if the rings were solid, every part must rotate in the same time. Thus, they are not solid, but are composed of myriads of meteors.

Satellites of Saturn.—On March 25, 1655, Huyghens, the discoverer of the rings, observed two small stars near to Saturn. One of these he suspected to be a satellite, and on the following night his suspicions proved correct, as the planet had moved and

carried with it one star, while it left the other behind. This satellite, which is called Titan, is supposed to be a little larger than the third satellite of Jupiter, and therefore exceeds the planet Mercury in size. In 1671 Cassini discovered a satellite which was afterwards named Japetus, and during the next thirteen years three more, which were named Tethys, Dione, and Rhea. For over a hundred years no more additions were made to the system of Saturn, but in 1787 Sir William Herschel, with one of his immense reflectors, found two interior satellites, which were named Enceladus and Mimas. In 1848 another satellite, now named Hyperion, was detected independently by Bond and Lassell, in America and England respectively. The ninth and tenth satellites were both discovered on the other side of the Atlantic. The ninth was discovered in 1898, by Professor W. H. Pickering, by means of photography, and its existence was confirmed in 1904. The satellite was named Phœbe, and was found to be the most distant of all Saturn's moons. It revolves round Saturn in the opposite direction from the others—a remarkable and almost inexplicable fact. Another satellite was found in 1905 by the same astronomer, and named Themis. Its period and mean distance are almost the same as those of Hyperion.

It was discovered by Herschel that Saturn rotated on its axis in 10 hours 16 minutes. This has been confirmed by subsequent observers, although in 1903

a white spot gave a period of 10 hours 37 minutes. Saturn, like Jupiter, is very much flattened at the poles. There are belts on Saturn similar to those on Jupiter, and it is believed that, like the giant planet Saturn has not yet parted with its heat. Indeed, Saturn is probably even hotter than Jupiter, for though about 700 times as large as the Earth, it is only ninety times as heavy. In fact, supposing Saturn could be flung into a great ocean, it would actually float, being only equal in weight to a globe of walnut wood the same size.

Discovery of Uranus.—Up till the year 1781 Saturn was regarded as the outermost planet of the Solar System, none farther from the Sun being supposed to exist. Mercury, Venus, the Earth, Mars, Jupiter, and Saturn, along with the Sun, made seven planets, and seven was regarded as "the perfect number," there being seven days in the week. All the great planets had been known for so long that their discoverers were lost in the mists of antiquity, and no one even suspected that there might be other members of the Solar System still undiscovered.

On March 13, 1781, William Herschel was exploring a region of the heavens in the constellation of Gemini with a telescope of his own construction. He examined a large number of stars, but presently he came on something which was plainly not a star. Even in the most powerful telescopes a star appears

as a point of light, owing to the immense distance of the stars proper from the Earth. The object which Herschel found showed a round disc like the planets. The great astronomer, however, never suspected that what he had observed was a new planet, and accordingly he announced that he had discovered a comet without a tail. The new "comet" was observed by Maskelyne, the Astronomer-Royal of England, who suspected it to be a planet.

After a comet has been discovered, it is the custom for mathematical astronomers to make calculations to see whether it moves in a parabola or a very long ellipse. Laplace and others found that the new member of the Solar System neither moved in a parabola nor a very long ellipse. Its orbit was nearly a circle, and in January 1783 Laplace proved beyond all doubt that it was a planet. Herschel, for his great discovery, was summoned to London to visit King George III., and he was appointed "King's Astronomer."

The name of the new planet gave rise to controversy. The French astronomers suggested the name "Herschel," after its discoverer, but that title was never accepted. In honour of King George III. Herschel named the planet "Georgium Sidus," or "George's Star." "The Continental astronomers, however," writes Sir Robert Ball, "thought that the King of England would seem oddly associated with Jupiter and Saturn." The German astronomer Bode sug-

gested "Uranus," and by this name the planet is now known.

Satellites of Uranus.—On January 11, 1787, Herschel discovered two satellites to Uranus, now known as Titania and Oberon. For a time he thought he could see other four, making six altogether; but what he took for satellites must have been either small stars which happened to lie near the apparent path of the planet, or imperfections in the telescope, as they have never since been seen. In 1847, however, other two satellites were found, one by the astronomer Lassell, the other by the famous astronomer, Otto Struve. The new satellites were named Arièl and Umbriel, and make a total of four attendants to the planet Uranus. Strange to say, these satellites, instead of moving in the general direction from west to east, revolve in a retrograde direction, or from east to west, like the ninth satellite of Saturn.

Little is known of Uranus. It revolves round the Sun in eighty-four years at a distance of nearly 2000 million miles, and its mean diameter is about 31,000 miles. It probably rotates on its axis in about ten hours, and its disc appears to be striped with belts similar to those on Jupiter and Saturn, but so faint, owing to the planet's immense distance from us, that none but the very largest telescopes will show them.

Discovery of Neptune.—After the discovery of

Uranus by Herschel, an orbit was calculated for it. Astronomers predicted that it would be in a certain position on a certain date, but, strange to say, it was not in that position. The irregularities in the planet's movements were very small, so small that the difference in position could not be detected without the aid of a telescope. Irregularities of this kind are, however, too large to be permitted in an exact science such as astronomy. A French astronomer, Alexis Bouvard, inquired into the difficulty in 1821, and came to the conclusion that the previous observations were incorrect. For a while the problem seemed to be solved, but in a few years it was evident that something was attracting Uranus from its orbit. It was at first thought that the irregularities might be due to the attractions of Jupiter and Saturn; but after these had been accounted for it was seen that Uranus was influenced by some unknown body. In 1843 a young English astronomer — Adams — determined to solve the problem. He made mathematical calculations, and arrived at the conclusion that the irregularities could be accounted for by the existence of another planet revolving beyond Uranus, the position of which he computed; and in 1845 he sent his results to Airy, the Astronomer-Royal of England, and asked him to make a telescopic search for the disturber of Uranus. Airy, however, did not put much faith in Adams' calculations, and he did not search for the planet, which he might easily have done.

At this time the French astronomer Le Verrier had been urged by Arago to study the question. They were quite ignorant of the fact that Adams had already solved the problem, and Le Verrier came to the same results as Adams. Before the telescopic discovery of the planet, some papers written by Le Verrier happened to reach Airy. He was so struck with the resemblance to those of Adams, that at last he took Adams' calculations seriously, and wrote to Professor Challis of Cambridge, asking him to search for the unknown planet. Challis, however, had no star-maps, and he had to make them before he could begin the search. This delay caused Adams to lose the glory of the discovery.

In September 1846 Le Verrier wrote to Encke, director of the Berlin Observatory, to search in the constellation Aquarius for the unknown planet. The astronomers at Berlin had one advantage which Challis lacked. They had star-maps; and on September 23, Galle, Encke's assistant, found the planet in the place indicated by Le Verrier. It was also observed at Cambridge on September 29, and received the name of Neptune. There was an unpleasant controversy as to which of the two astronomers deserved most credit. It is now, however, admitted that the honour must be divided equally between them. While Adams was earlier with his results, Le Verrier's were slightly more accurate.

On October 10, 1846, Lassell, with his great reflec-

tor, discovered a satellite revolving round Neptune. The existence of another satellite was also suspected for some time, but the suspicions were not confirmed. This satellite revolves, like the satellites of Uranus, in a retrograde direction. It must be very large to be visible at such an immense distance. Indeed, it is believed to be the largest satellite of the Solar System. Astronomers are not quite agreed as to its exact size, but probably it is 3000 miles in diameter.

Neptune is situated at the immense distance of almost 3000 millions of miles from the Sun, round which it requires almost 165 of our years to revolve. It will thus be seen that if little is known of Uranus, still less must be known of Neptune. Its diameter is about 34,000 miles. It is slightly larger than Uranus, and is in size the third planet of the system. Its rotation period is quite unknown, as no markings have ever been seen on its surface.

It is quite possible that there may be one or more planets beyond the orbit of Neptune. Two separate trans-Neptunian planets have been suspected and searched for, but hitherto without success. But this is not to be wondered at, considering the vast distances at which such planets, if they exist, must be situated.

Origin of Solar System.—That the Solar System has not always existed in its present form has been

the opinion of men of science from the earliest ages. But the first comprehensive effort to explain the evolution of the Solar System was by means of the nebular theory. This theory, modified by subsequent research, seems to be now generally adopted. James Ferguson and Kant, in the middle of the eighteenth century, foreshadowed the nebular theory. But the actual theory as we now know it was first propounded by Laplace in 1796, and independently by Herschel in 1811.

The Nebular Hypothesis.—In 1796, at the end of a popular work named 'Système du Monde' (System of the World), Laplace put forward his Nebular Theory. It was from certain similarities in the Solar System that he formed his idea. He noticed that the planets all revolved round the Sun, and the satellites round their primaries, in nearly the same plane as the Earth, the ecliptic. There was no reason why they should all move in that plane more than in any other. Laplace also observed that all the planets and satellites moved in the same direction —viz., from west to east. They could have as easily moved in opposite directions. It is certain that the similarity of the planetary movements are not coincidences. According to Sir Robert Ball, "there are a million chances to one in favour of the supposition that the disposition of the movements of the planets has not been the result of chance." Since the days of

Laplace seven hundred asteroids have been discovered, and every one of them moves from west to east. Another fact noticed by Laplace was that the Sun and planets all rotated on their axes from west to east. Now there was no reason why some should not move in one direction and some in the other. Laplace, therefore, to explain these coincidences, expressed the view that the Solar System had originated from a great nebula, which, slowly contracting, now forms the Sun, leaving behind it the planets and their satellites. The fact that the Sun is still contracting lends great probability to the nebular theory.

It was from observing the sidereal heavens that Herschel was led to the nebular theory independently of Laplace. In 1811 Herschel said that the nebulæ were gaseous. He pointed out that he could trace every stage between the widely diffused nebulæ and perfect systems, such as the Solar System. In other words, that the nebulæ became transformed into stars. Laplace and Herschel independently enunciated the nebular theory, the one from noticing the coincidences in the Solar System, the other from observing the stars.

It used to be said that the nebular theory was in direct opposition to revealed religion, and that it was contradictory to the Bible. Nowadays, however, it is recognised that there is nothing in an evolutionary theory of the Solar System to contradict the account of the Creation in the Book of Genesis. While

millions of years, and not six days, are required for the evolution of our system, according to the nebular hypothesis, we must remember that "One day is with the Lord as a thousand years, and a thousand years as one day" (2 Peter iii. 8). In the words of the late Rev. Hugh Macmillan: "Could such a theory be established, it would tend to exalt, instead of lowering, my ideas of God as a God of order, and of the creation as a gradually developed and slowly unfolded artistic production."

CHAPTER VI.

COMETS AND METEORS.

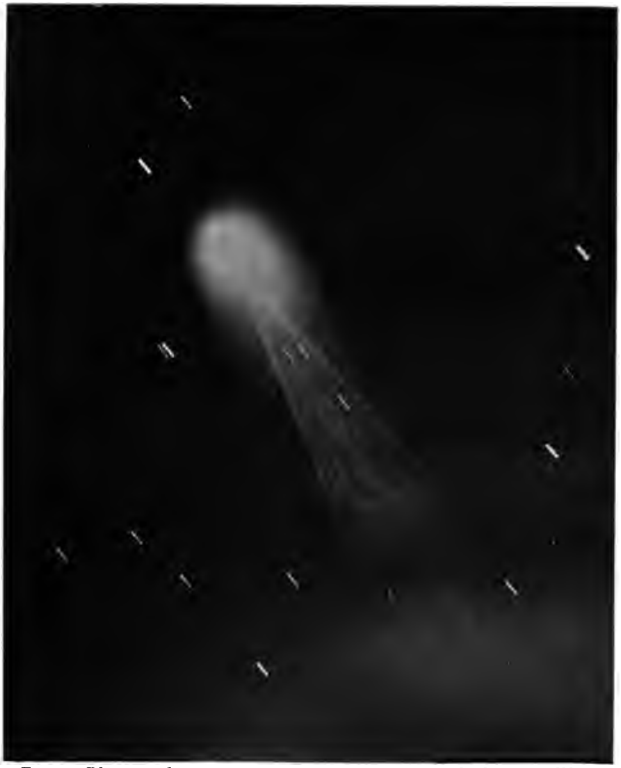
Ancient Superstitions.—In the olden times the appearance of a bright comet or "hairy star" was regarded as a dire calamity. Not only the ignorant but the learned, not only theologians but men of science themselves, believed that comets were the cause of numberless evils and the mark of Divine displeasure. In the Middle Ages, as Professor White, an American scientist, remarks, it was commonly believed that "every comet is a ball of fire flung from the right hand of an angry God." Able and shrewd men like Martin Luther and John Knox shared in the popular superstition. It is recorded of a certain Pope of Rome that at a time when the Turks were causing considerable trouble a bright comet appeared; the Pope connected the two circumstances, and solemnly excommunicated the Turks and the comet!

In our own day comets are regarded, not with

fear, but with wonder and admiration. A severe blow was given to the popular superstition when it was proved that comets are subject to the law of gravitation, just as planets are.

Halley's Comet.—The great comet of 1682 was observed by Halley, who was struck with the similarity between it and descriptions of comets which had previously appeared at intervals of seventy-five or seventy-six years. He therefore predicted that the comet would return to perihelion —or point nearest the Sun—in the end of 1758 or beginning of 1759. His prediction was fulfilled with wonderful accuracy. On Christmas Day 1758 the comet was first observed by a farmer in Saxony. It passed perihelion in the spring of 1759. This was a little later than Halley had predicted, but, considering that Uranus and Neptune were then unknown, and their attractive influences consequently left out of the calculation, it was wonderfully near the truth. Halley's Comet returned again in 1835, and it will reappear in 1910.

The next of the periodic comets to be discovered was that which bears the name of Encke. It was discovered in the end of 1818 by a French astronomer named Pons, at Marseilles, and the eminent German astronomer Encke calculated an orbit for it, predicting that it would return over three years later, or in 1822. The comet did return, and has reappeared ever



From a Photograph *by Dr Max Wolf.*

DANIEL'S COMET, 1907.

since. Many other periodic comets besides those of Halley and Encke are now known, and they are recognised as regular members of the Solar System. Many of the most famous comets are not periodic, or else if they are, their periods are so long as to be indeterminate. To this class belongs the famous comet of 1858, discovered by Donati at Florence, and known as Donati's Comet.

Bright comets appear in the heavens at very irregular intervals. Telescopic comets, on the other hand, are always to be seen, as there are generally some visible. The central point of a comet's head is called the nucleus, and surrounding this is the coma, or hair, so named on account of its hairy appearance. From the coma stretches the tail, which often streams for millions of miles. While bright comets have tails of respectable dimensions, faint telescopic comets are often tailless, and, indeed, this tailless class of comet is the commonest.

Tails of Comets.—It has long been noticed that the tail of a comet always points away from the Sun; and Olbers, who was the greatest authority on comets a hundred years ago, devised the theory that the tails of comets were vapours repelled from the nucleus by the repulsive force of the Sun. This theory has been considerably elaborated since Olbers' day by Zöllner and Brédikhine. The last-named astronomer divided the tails of comets into three types—firstly,

long straight tails; secondly, tails considerably curved; and thirdly, short brush-like tails, strongly bent. Brédikhine concluded that the tails of the first type are formed of hydrogen, tails of the second type of hydrocarbon, and tails of the third type of iron, with a mixture of other elements, including sodium. The spectroscope has demonstrated that comets shine partly by inherent and partly by reflected light. Iron and sodium were identified in the great comet of 1882, while the hydrocarbon spectrum is typical of all comets.

Biela's Comet.—It is possible, however, that astronomers have learned more of the constitution of comets from the study of one small member of the Sun's comet-family than from all the other comets combined. A telescopic comet was discovered by Von Biela, an Austrian officer, on February 27, 1826, and also observed the next month by a Frenchman named Gambart. In 1832 the return to perihelion of Biela's Comet caused a great panic, especially in Paris. Olbers, in 1828, published calculations to the effect that the comet would cross the Earth's orbit at a point which would be occupied by the Earth a month later. This set the people of Paris in a panic, as it was considered that if a comet struck the Earth our planet would be destroyed by fire. The panic only abated when Arago announced that, even when closest together, the Earth and Biela's Comet would

be 50 millions of miles apart. Biela's Comet again returned to perihelion in 1846, and it was at this return that it mysteriously divided, and journeyed through space as two comets. Both the comets were observed again in 1852, and the distance between them was greater than in 1846. At the next calculated return the comets failed to appear, and in November 1872, when the Earth crossed the comet's path, there was a magnificent display of shooting-stars or meteors. As the late Miss Clerke remarks, it was evident that "Biela's Comet was shedding over us the pulverised products of its disintegration." In 1885 and 1892, when the Earth also crossed the comet's path, there were showers of meteors. Biela's Comet no longer exists: it has become dissolved into a straggling shoal of meteors.

This comet of Biela supplied a fairly good answer to the question—What is a comet? Schiaparelli defines a comet as a "cosmical cloud." These cosmical clouds, says the Italian astronomer, become disintegrated, and "the meteoric currents are the products of the dissolution of comets, and consist of minute particles which certain comets have abandoned along their orbits, by reason of the disintegrating force which the Sun and planets exert on the rare materials of which they are composed."

Meteors.—These "products of the dissolution of comets" are known as shooting-stars or meteors.

They are very familiar objects, for a clear night never passes without several meteors being seen by a careful observer. In the words of Flammarion: "Sometimes, when night has silently spread the immensity of her wings above the weary Earth, a shining speck is seen to detach itself in the shades of evening from the starry vault, shooting lightly through the constellations to lose itself in the infinitude of space."

Showers of Meteors.—On some occasions, however, meteors are observed, not in twos or threes, but in dense showers. From the earliest ages showers of shooting-stars have been observed. There was a great shower of meteors, it is recorded, in the year 902 A.D., the shower being associated with the death of a Moorish king. There was a shower in November 1799, observed by Humboldt in South America, and there were also great showers in 1833 and 1866. Thus, on an average, there is a shower of November meteors every thirty-three years. After the meteors of 1833 it was observed that all the little bodies fell from one portion of the sky, the constellation Leo, thus gaining the name of the "Leonids." In 1864 the late Professor H. A. Newton, an American astronomer, having records of meteoric showers every thirty-three years, predicted a great shower on the night of November 13 and morning of November 14, 1866. The prediction was fulfilled; and finally, Adams, one of the

discoverers of Neptune, proved by mathematical calculation that the Leonids revolve round the Sun in an elliptical orbit in thirty-three years. The Earth crosses the meteoric orbit every year, and a few meteors are seen in November, but it is every thirty-three years that our planet crosses the great cluster. A meteoric shower was predicted for 1899 or 1900, but, strange to say, it did not take place. There were slight showers in 1901 and 1904, but they were by no means striking; and the general idea is that either the main shoal of meteors has become disintegrated or else it has been attracted off its path by planetary influences. Soon after the shower of 1866 it was found independently by the Italian astronomer Schiaparelli, and an American observer, Dr C. F. W. Peters, that a comet moved in the same orbit as the Leonids. In fact, the Leonid meteors are merely the remains of the breaking-up comet.

There is a famous shower of meteors in August, known as the "Perseids," because they appear to radiate from the constellation Perseus. In 1862 a comet was discovered, and proved to revolve in an orbit identical with the Perseids. In other words, the Perseids are the broken-up portions of another comet. The Lyrid meteors of April are also associated with a comet, and, of course, as already mentioned, Biela's Comet appears to have been broken up into meteors.

Thanks to the labours of several able astronomers,

chief among them Mr W. F. Denning of Bristol, we are now acquainted with many of these showers. The Earth crosses the orbits of meteoric systems many times in a year. Our planet ploughs its way through the swarm, and the little meteors, originally cold and dark, in the rush through our atmosphere, are raised by friction into vapour, eventually falling to the Earth as dust. In the striking language of Sir Robert Ball: "At last the fatal plunge is taken. The long wanderings of the meteor have come to an end, and it vanishes in a streak of splendour." Besides the meteoric swarms described, there are many others which the Earth encounters in its annual journey round the Sun. Every twenty-four hours, it has been calculated, four hundred million meteors fall to the surface of the Earth.

Aerolites.—Some meteors fall to the ground and are not wholly destroyed by heat. These, however, are comparatively rare, and are known as Meteorites or Aerolites. For instance, a meteorite which fell in the United States killed a man and felled a tree, eventually making a hole two feet deep in the ground. At Rowton, in Shropshire, on April 20, 1876, a piece of iron fell and buried itself in a field. When dug out it was hot, and it is now preserved in the British Museum. There are other instances of bodies falling from the sky. In 1881 a stone weighing three pounds fell in Yorkshire on the railway

line, and made a hole eleven inches deep. On November 23, 1877, a meteorite exploded with a loud report over the town of Chester. On February 23, 1879, a great meteorite burst over York with a noise like a loud peal of thunder; and in 1876 a meteorite which passed over the United States broke up into small fragments and made such a noise that some people thought an earthquake must have happened.

The Capture Theory.—It has been calculated that some of the comets and meteor streams which now belong to the Solar System were originally visitors who were captured by the influences of the planets. Le Verrier, for instance, actually assigned a date for the capture of the Leonid stream and its attendant comet. It is quite possible that while many comets and meteor streams originated in the Solar System, numbers of them have come originally from the depths of the interstellar regions, and are therefore the messengers of space.

The great comet which appeared in 1811 was made the subject of a poem by James Hogg, "the Ettrick Shepherd," of which a few verses may be quoted.

"Stranger of heaven, I bid thee hail!
  Shred from the pall of glory riven,
That flashest in celestial gale
  Broad pennon of the King of Heaven.

duced to ten feet, fourteen miles would separate our system from the nearest of the stars. The stars are suns, and our Sun, great as it may seem to us, is no more than an inferior star. Distance is often very deceptive. The planet Jupiter, for instance, shines many times more brightly than Sirius or Arcturus, and yet Jupiter sinks to utter insignificance compared with even the faintest of the stars.

The aspect of the heavens is continually changing. The rotation of the Earth on its axis causes the stars to appear to move from east to west. Every night, however, the stars seem to set four minutes earlier, owing to the motion of our planet round the Sun. The result is that the stars change constantly, and at the end of 365 days return to the same positions. The North Pole of the Earth points to a bright second-magnitude star in Ursa Minor, known as Polaris, or the Pole Star. All the other stars appear to revolve round this star, which scarcely changes its position. The northern stars, therefore, do not set.

The Constellations.—The stars are divided into groups or constellations which cut up the whole sky. Some of these constellations are very conspicuous. The famous group of Ursa Major, the Plough, or Charles' Wain, as it is variously called, is to be seen on every clear night, as it never sinks below the horizon. In the south during winter is seen the most brilliant constellation in the heavens, Orion, which is

easily recognised by the three stars forming the "belt." Round Orion are the constellations Taurus (which contains the Pleiades), Gemini, and Canis Major, the latter containing Sirius, the brightest of the stars proper. Some of the constellations have been known from very ancient times, as will be seen from the following allusion to the heavens in the Bible (Job xxxviii. 31, 32): "Canst thou bind the cluster of the Pleiades, or loose the bands of Orion? Canst thou lead forth the Mazzaroth in their season, or canst thou guide the Bear with her train?" [1]

There are twenty-one stars of the first magnitude, of which, however, several are invisible in this country. Several of the stars have special names, but the brightest stars in each constellation are known by the letters of the Greek alphabet, and when these are exhausted numbers are used.

Distance of the Stars.—The enormous distance which Copernicus claimed for the stars was for long considered a great drawback to the acceptance of his theory. The old astronomers believed the stars to be quite near, merely luminous points in the sky. Copernicus said they must be placed at such enormous distances as would show only a very small displacement in position. In order to measure the parallax of the Sun, Moon, and planets, two observers have to proceed to the opposite ends of the Earth

[1] Revised version.

and observe the displacement in position of the objects, after which there is some mathematical calculation, and the problem is solved. With the stars, however, the case is very different. An astronomer makes an observation on a certain star, say, in January, and six months later, in July, he observes again and notices a displacement in the position of the star. Sometimes there is no visible displacement, and the distance cannot be measured. An idea of the difficulty of observing stellar parallax will be gathered from the remark of an American writer, Mr Garret P. Serviss, that the displacement "is about equal to the apparent distance between the heads of two pins placed an inch apart and viewed from a distance of a hundred and eighty miles."

Measurement of Star-distance.—Many of the earlier observers, among them Bradley and William Herschel, tried to measure the parallaxes of the stars and failed. Until about seventy years ago star-distance remained one of the problems of science. At this time, however, two successful attempts to measure the sidereal parallax were made independently at the same time by the German astronomer Bessel and Thomas Henderson, the great Scottish astronomer, who afterwards became Astronomer-Royal of Scotland. Bessel measured the distance of 61 Cygni, a small, insignificant star of the fifth magnitude in Cygnus. Henderson, in South Africa,

fixed his attention on the great southern star, α Centauri. Bessel was two months earlier with his results than Henderson, and both were wonderfully accurate. α Centauri is twenty-five billions of miles away, 61 Cygni forty-three billions. The distances are so vast that light, which takes only eight minutes to pass from the Sun to the Earth, takes four years in its journey from α Centauri, and seven years from 61 Cygni. The parallaxes of several other stars have also been roughly measured. Sirius is about fifty-eight billions of miles away, and light is eight years on the journey. The well-known Pole Star is situated at such a vast distance that light requires about forty-seven years to travel, and there are stars in the heavens the light of which takes thousands of years to reach the Earth.

Proper Motions.—The stars are so enormously distant that, although they are moving with great rapidity, the change of position can only be detected after years of careful and refined observations. The bright star Arcturus is moving at a velocity of over two hundred miles per second. The swiftest star known, however, is an eighth-magnitude star in the southern hemisphere, to whose rapid motion Professor Kapteyn called attention in 1897. It would take two hundred years for that star to move over a space equal to the Moon's diameter.

Star-drift.—Some stars share their "proper motions" with others. Thus, Flammarion has discovered that the bright star Regulus and a faint star of the eighth magnitude have a common proper motion. In the case of the Plough, too, Proctor found that five of the well-known seven stars have a common proper motion. This phenomenon is known as star-drift. By means of Doppler's principle, referred to in the chapter on the Sun, astronomers are able to measure the motions of the stars in the line of sight. Sir William Huggins was the first to make observations of this kind. His pioneer work was followed up by the late Dr Vogel, who applied photography to the study and determined the motions of many stars.

Motion of the Sun.—Like the stars, the Sun itself has a proper motion. In 1783, Herschel, from observations of the displacements of the other stars, ascertained that the Sun is moving towards Hercules. Modern astronomers, with more perfect data on which to work, have found that our Sun is moving towards the neighbouring constellation Lyra, carrying with it all the planets and comets, at the velocity of eleven miles per second; so in addition to our Earth's motion on its axis and round the Sun, it follows the Sun in its unending voyage through space.

"Such," says Flammarion, "are the stupendous

motions which carry every sun, every system, every world, all life and all destiny in all directions of the infinite immensity, through the boundless, bottomless abyss; in a void for ever open, ever yawning, ever black, and ever unfathomable; during an eternity without days, without years, without centuries or measures. Such is the aspect, grand, splendid, and sublime, of the Universe which flies through space before the dazzled and stupefied gaze of the terrestrial astronomer, born to-day to die to-morrow on a globule lost in the infinite night."

Arcturus.—Some of the first-magnitude stars are worthy of special mention. Arcturus is supposed to be the greatest sun visible from the Earth. By means of reliable calculations, astronomers have arrived at the conclusion that the diameter of Arcturus is no less than 62 million miles. Compare it with that of the Sun—888,000 miles! In his work, 'Pleasures of the Telescope,' Mr Garret P. Serviss writes: "Imagine the Earth and the other planets constituting the Solar System removed to Arcturus, and set revolving round it in orbits of the same forms and sizes as those in which they circle about the Sun. Poor Mercury! For that little planet it would indeed be a jump from the frying-pan into the fire, because, as it rushed to perihelion, Mercury would plunge more than 2,500,000 miles beneath the surface of the giant star. Venus and the Earth would melt like snowflakes at the

mouth of a furnace. Even far-away Neptune would swelter in torrid heat."

Placed at the distance of Capella, the brightest star in Auriga, the Sun would shine as a star of the sixth magnitude, which shows the superiority of Capella. According to Mr Gore, Capella has a diameter of no less than 14 million miles, and is equal in volume to four thousand suns such as ours. Rigel, the brightest star of Orion, is placed at such an enormous distance that Sir David Gill has failed to measure its parallax. Rigel and Arcturus are probably the greatest stars visible from the Earth.

Stellar Spectra.—Like the Sun, each of the stars has its own distinct spectrum, with its own particular lines. In 1864 Sir William Huggins particularly studied the spectra of the stars Betelgeux and Aldebaran. In the former, sodium, iron, calcium, magnesium, and bismuth were detected. The stars have been classified into groups according to their spectra. Secchi, the famous Italian astronomer, made the first classification in 1863. He divided the stars into the following four general types:—

Type I.—The White Stars, of which Sirius, Vega, Rigel, Altair, Spica, Regulus, Castor, Algol, &c., are examples.

Type II.—The Yellow Stars, such as the Sun, Canopus, Capella, α Centauri, Arcturus, Aldebaran, Procyon, Pollux, the Pole Star, &c.

Type III.—The Red Stars, such as Antares, Betelgeux, &c.

Type IV.—The deeply coloured Red Stars, which are comparatively scarce in the heavens.

To Secchi's four types a fifth was added in 1867 by two French astronomers, Wolf and Rayet, which are known as the "Wolf-Rayet" stars. Less than a hundred stars of this type have been discovered. A more complete classification was made by the late Dr Vogel. He subdivided the first type into three classes, the second type into two, and included both the third and fourth types in his Type III. In 1895 he separated from the first type a numerous class of stars in which the element helium had been identified by his assistant Dr Scheiner, and designated this newly formed class as "Type O." They are also known as "Orion stars."

Double Stars.—In the year 1664 an English astronomer named Hook, while observing a comet in the constellation Aries, noticed that the star γ of that constellation was double—that is, it consisted of two stars close together. This discovery was followed by others, and double stars came to be recognised as not uncommon in the heavens. It was generally thought, however, that they were merely the result of two stars appearing to lie in the same region of space, but having no connection with each other. Double-star

astronomy remained at a primitive stage until the days of William Herschel.

In 1802 Herschel announced to the world one of the greatest discoveries which has ever been made in astronomy—namely, that in the case of many of the double stars the smaller star revolved round the larger; in other words, that the law of gravitation extended to the stars. Isaac Newton had, in the seventeenth century, shown that gravitation, already known to exist on the Earth, explained the movement of the Moon round the Earth, and of the planets round the Sun. But it was not known whether gravitation was merely a local law belonging to the Solar System or not. Herschel showed that the law existed throughout the Universe.

Herschel made his great discovery while searching for the parallaxes of the stars. He could find no parallax, and did not solve the problem of star-distance. He had been observing certain bright double stars for many years, and found that the smaller star shifted its position slowly until it completed a revolution around its primary. Herschel, to distinguish between "optical doubles" and revolving stars, gave to the latter the name of "binary" stars. After the days of Herschel, much attention was paid to the binary stars by his son, Sir John Herschel, and the two Struves, Wilhelm and Otto. These three observers added greatly to the number of known binary stars, which are at present to be counted by thousands.

The greatest living observer of double stars is Professor Burnham of Chicago, who has found over 1200 double stars.

Some of the most famous binary stars in the heavens are ζ Herculis in the constellation Hercules; Castor, in Gemini; α Centauri, 70 Ophiuchi, γ Coronæ Borealis, γ Virginis, 42 Comæ Berenices. In the case of Castor, John Herschel in 1833 computed an orbit of 252½ years. Mädler considered the period of revolution to be 199 years. More recent observations, however, show that the star revolving round Castor probably requires 1000 years. Sirius, the brightest star in the sky, is also a double star. In 1844 Bessel observed irregularities in its motion, and ascribed this to the gravitational influence of a large satellite-star. An orbit was computed for this star, and close to the indicated position it was discovered in 1862. Procyon has also a satellite-star, whose existence was foretold by Bessel. It was telescopically detected in 1896 at the Lick Observatory.

Colours of Double Stars.—Double stars often exhibit great variety of colours. Antares, a fiery-red, first-magnitude star in Scorpio, is attended by a small green sun, and there are many other instances. For long it was thought that star colours were merely the effect of contrast. This, however, has been found to be erroneous by the spectroscopic observations of Sir William Huggins. The colours

the eternity of the veritable Empyrean! Eternal clocks of space! your motion does not stop; your finger, like that of Destiny, shows to beings and things the everlasting wheel which rises to the summits of life and plunges into the abysses of death! And from our lower abode we may read in your perpetual motion the decree of our terrestrial fate, which bears along our poor history and sweeps away our generation like a whirlwind of dust flying on the roads of the sky, while you continue to revolve in silence in the mysterious depths of Infinitude!"

CHAPTER VIII.

THE STELLAR UNIVERSE (*continued*).

Variable Stars.—A considerable number of the stars are unstable in their light and exhibit variations, either periodical or regular. These stars are known as variables. The first variable star was detected in 1596 by a Dutch astronomer, Fabricius. It is known as Mira Ceti, or the wonderful star of Cetus. Since that time the discovery of variable stars has gone on steadily, until the variable-star catalogues contain the names of thousands of stars. In recent years many able astronomers have devoted themselves to the study of these stars, among them Mr Gore in Ireland, Dr Dunér in Sweden, Dr Anderson at Haddington, Scotland, and Dr A. W. Roberts — a Scotsman—in South Africa. Professor Pickering, in 1880, classified the variable stars as follows: Class I., temporary stars; Class II., stars undergoing in several months large variation, such as Mira Ceti; Class III., irregular variables, such as Betelgeux;

Class IV., short-period variables, such as β Lyræ and δ Cephei; Class V., "Algol variables." The period of Mira Ceti is about 331 days, but it is not very regular: the range of its variation is great. Sometimes at maximum it is much brighter than at others. For instance, in 1906 it was brighter than the second magnitude. Its variations appear to be the result of great internal disturbances, and the same theory probably applies to all variables of long period.

Algol.—The fluctuations in the light of Algol, which occupy 2 days 20 hours 45 minutes 55 seconds, were probably observed by the old Arabian astronomers, and were re-discovered by an Englishman named Goodricke in 1782. He supposed that the variations in Algol's light were caused either by a partial eclipse of the star by a dark satellite, or by one-half of Algol being covered by spots, and reflecting less light than the other. Professor E. C. Pickering, in 1880, found that a dark satellite revolving round Algol in 2 days 20 hours 45 minutes 55 seconds would explain the variation. The theory of a dark satellite was proved by Vogel of Potsdam, by means of Doppler's principle, in 1888 and 1889. Not only has Professor Vogel found that theory to be correct, but he has arrived at the conclusion that Algol is a star one million miles in diameter, the dark companion being 800,000 miles—about the size of

the Sun. The distance between the two is about three million miles. From certain irregularities in the movements of Algol, Dr Chandler, an American astronomer, considers it probable that Algol revolves round a dark globe in 180 years, at a distance of about 1800 million miles. Thus, though we have never seen the satellite of Algol, we know that it exists, and though we do not know its distance from us, we can tell its possible size.

Dr A. W. Roberts has made a special study of these Algol variables, and has detected some in the southern hemisphere, in which the component stars revolve in contact.

Eta Argus.—Half-way between variable and temporary stars is η Argus, a star in Argo Navis, invisible in Europe. At present η Argus is of the seventh magnitude, and cannot be seen without the aid of a telescope. When Halley visited St Helena to observe the southern stars in the seventeenth century, it was of the fourth magnitude. A hundred years later, a Frenchman, La Caille, noted it as of the second magnitude. In 1837, however, it was brighter than the first-magnitude stars Procyon, Betelgeux, and Rigel, and continued to increase until January 1838, when it equalled α Centauri. At this time η Argus was observed by Sir John Herschel, who some time later noted it equal to Aldebaran. Then it began to decrease. In 1843

it increased again, its brilliancy being equal to Canopus, and only surpassed by Sirius. After that it again declined, and is still inconspicuous. It can neither be called variable nor temporary.

Temporary Stars.—The temporary stars—of which the most famous have been those which appeared in 1572, 1604, 1866, 1876, 1892, and 1901—have been suspected of being merely "long-period variables." This, however, is practically disproved. The new star which appeared in Cassiopeia in 1572 was observed by Tycho Brahe. According to his description, it surpassed the planet Jupiter in brightness, and was equal to Venus. In 1573 the star vanished, and, of course, there were no telescopes to observe it further during its decrease. The star of 1572 has been suspected by some of being a variable with a period of three hundred years, but there are no signs of its reappearance. The star of 1604 was observed by Kepler. It was of the first magnitude in October 1604, and was afterwards equal to Jupiter. It vanished early in 1606.

The new star of 1866 in Corona Borealis was first discovered by an Irishman named Birmingham on May 12, 1866. It was spectroscopically examined by Sir William Huggins. It showed the common spectrum of a star at first, and later, hydrogen appeared prominent. It is probable, therefore, that there was on the star a great outbreak of incan-

descent hydrogen. In 1876 a star of the third magnitude in Cygnus was discovered by Schmidt, and then died out. In 1885 a star appeared in the centre of the Andromeda nebula.

In January 1892 Dr Anderson in Edinburgh discovered a new star of the fourth magnitude in Auriga. In March it faded rapidly in brightness, and by the end of the month it sank to the twelfth magnitude. In August it rose again to the ninth magnitude, finally decreasing to the position of a very minute star. Its spectrum was examined by Sir William Huggins, Sir Norman Lockyer, Professor Vogel, and Professor Campbell. At first Nova Aurigæ showed the ordinary spectrum of a star, which afterwards changed to that of a nebula. It has been suggested that two dark stars rushing through space collided, and were raised by friction into glowing gas, thus explaining the outbreak of the star.

Nova Persei.—On February 21, 1901, a new star of the second magnitude in Perseus was discovered independently by Dr Anderson and a number of other observers. After its discovery it rapidly increased in brightness, and in two days it actually surpassed Capella, one of the brightest stars of the first magnitude. In March it decreased to the third magnitude, and in April to the fifth. Its spectrum exhibited changes similar to those of Nova Aurigæ.

On June 25, 1901, Professor Pickering reported that its spectrum had been gradually changing into that of a gaseous nebula.

Besides these bright temporary stars, numerous fainter ones have been detected, mostly on the photographs taken at the Harvard College Observatory. Many theories have been advanced to explain temporary stars, but the most probable seems to be that of Professor Seeliger. This theory regards these outbreaks as due to the passage of dark stars through masses of nebulous matter.

Nebulæ.—The heavens abound with these nebulous masses, and two of them are partially visible to the naked eye. On a clear winter's night, when the Moon is invisible and the stars sparkle in thousands, the middle star of the "sword" of Orion may be seen to present a hazy appearance, and the smallest telescope will show it as a cloud on the dark background of the sky. This is the Great Nebula in Orion, considered by all astronomers to be one of the finest sights in the heavens.

The two most famous nebulæ in the heavens are the Great Nebula in Orion and the Great Nebula in Andromeda. Although the Great Nebula in Andromeda is more easily seen without telescopic aid than that in Orion, yet the latter is considered to be really a grander object. The Great Nebula in Orion was first observed by a Swiss named Cysat in 1618,

From a Photograph *by Dr Max Wolf.*

THE "NORTH AMERICA" NEBULA IN CYGNUS.

and it is considered remarkable that it was not discovered by Galileo. The first proper observation on it was made by Huyghens, who described the Great Nebula as follows: "In the sword of Orion are three stars quite close together. In 1656, as I chanced to be viewing the middle one of these with the telescope, instead of a single star, twelve showed themselves. Three of these almost touched each other, and, with four others, shone through a nebula, so that the space around them seemed far brighter than the rest of the heavens, which was entirely clear and appeared quite black."

After the time of Huyghens the nebulæ were neglected, and the next astronomer to study them was William Herschel. In March 1774, Herschel observed the Great Nebula in Orion with a small reflector, and it is interesting to note that, according to Miss Clerke, the same nebula was the last object observed with Herschel's forty-foot reflector. The Great Nebula in Andromeda was discovered by Halley, and is more easily seen with the naked eye than the Nebula in Orion. It is elliptical in shape, and has a small companion nebula, which was discovered by Herschel's sister, Caroline Herschel, in 1783.

Nature of Nebulæ.—In the end of the eighteenth century the general idea was that the nebulæ were all star-clusters, only too far away for the stars com-

posing them to be visible separately. Herschel, after sharing this view for a little, came to the conclusion that the nebulous light was "not of a starry nature," but represented huge masses of glowing gas. There was nothing, however, to prove beyond doubt that Herschel was right; and even Sir David Brewster, in 1854, in 'More Worlds than One,' declared that increase of telescopic power would resolve all the nebulæ, which, in his view, were star-clusters at enormous distances. Herschel's son, Sir John Herschel, also shared this view. Telescope after telescope was turned on the nebulæ with the hope of resolving them into stars, but the attempts proved useless. The common idea was that Herschel had been mistaken. The gigantic reflector erected by the Earl of Rosse at his estate in Ireland in 1845 was turned to the nebulæ. Lord Rosse himself considered that he had partially resolved the Orion Nebula, and that a little increase of telescopic power would prove beyond all doubt that it was a star-cluster. The refractor of Cambridge, Massachusetts, U.S.A., was said to have also accomplished the resolution of some of the nebulæ.

Only five years after Kirchhoff's discovery of the principles of spectrum analysis, Sir William Huggins, on August 29, 1864, turned the spectroscope on a nebula in Draco. The spectrum showed that the nebula was a mass of incandescent gas. In Sir William Huggins's own words: "These nebulæ are

shown by the prism to be enormous gaseous systems." Sir William Huggins then observed the Great Nebula in Orion, and proved that it was also composed of glowing gas, chiefly hydrogen. After all, Herschel had been right and Brewster wrong. Sir William Huggins has also shown that the Ring Nebula in Lyra and the "Dumb Bell" Nebula are gaseous. The spectra of the Great Nebula in Andromeda and the Great Spiral Nebula are more complicated, and they are believed to be in a further stage of their existence than the Great Nebula in Orion.

Classes of Nebulæ.—There are many various shapes of nebulæ. Some, like the Great Nebula in Andromeda, are elliptical; others, like the Ring Nebula in Lyra, annular; others round, like planets, and known as "planetary nebulæ"; others widely diffused, like the Great Nebula in Orion and the nebula surrounding η Argus; others spiral, like the nebula in Canes Venatici, and many other varieties.

Number of Nebulæ.—Some years ago the late Professor Keeler, director of the Lick Observatory, who died in 1900, devoted himself to nebular astronomy. The results he gained were striking. On one occasion Professor Keeler was photographing a certain nebula in the constellation Pegasus, and was

amazed, on developing the plate, to find that not only that nebula but twenty others had been photographed. In the constellation Andromeda, the Professor actually found thirty-two nebulæ reproduced on a small photographic plate. This shows what an immense number exist in the heavens. He considered that with the Crossley Reflector—the instrument with which he made his observations—120,000 new nebulæ would be visible, half of these probably spiral. More recently Professor Perrine, of the same observatory, announces that probably 300,000 nebulæ are within reach of the same instrument.

The gaseous nebulæ in the heavens are to be counted by thousands. We cannot measure the distance from us of any of them, and therefore we cannot tell their size. Sir Robert Ball, writing on the Great Nebula in Orion, says: "As the eye follows the ramifications of the great nebula, ever fading away in brightness until it dissolves in the background of the sky; as we look at the multitudes of stars which sparkle out from the depths of the great glowing gas; as we ponder on the marvellous outlines of a portion of the nebulæ, we are tempted to ask what the true magnitude of this object must really be. . . . The only means of learning the true length and breadth of a celestial object depends upon our first having discovered the distance from us at which the object is situated. Unhappily we are entirely ignorant of what this

distance may be in the case of the Great Nebula in Orion. . . . We shall, however, certainly not err on the side of exaggeration if we assert that the Great Nebula must be many millions of times larger than that group of bodies which we call the Solar System."

Star-clusters.—Many of the so-called nebulæ, however, are probably clusters. For clusters of stars are truly systems, in the same sense as nebulæ; and in many cases there is a connection between the two classes of objects.

The Pleiades.—The most famous star-cluster in the heavens is the Pleiades. It is to be seen northwest of Aldebaran during winter, sparkling brilliantly. It consists of six or seven stars visible to the naked eye, the brightest of which is Alcyone. With a telescope a great number of stars may be seen in the Pleiades; and recent photographs show all the principal stars to be surrounded by nebulæ. The Hyades is a less interesting cluster, surrounding Aldebaran. The cluster Præsepe, in Cancer, was the first object to which the term "nebula" was applied.

The grandest star-clusters, however, are invisible without the aid of a telescope. They are situated in Hercules and Centaurus, the latter being invisible in Europe. The cluster in Hercules is considered by some astronomers to be one of the three most inter-

esting objects in the heavens, the other two being the planet Saturn and the Great Nebula in Orion. The Scottish astronomer Nichol remarked that "probably no one who has beheld this cluster for the first time in a telescope of great power can refrain from a shout of wonder." Herschel considered that the cluster in Hercules contained fourteen thousand stars. A planet placed in the middle of the cluster would have no night. There would be continuous day. The constant state of affairs on such a planet is equal to the scene which would be observed on our planet if all the stars seen on the darkest and clearest night were to increase suddenly in brilliance until the faintest shone with light enough to banish night.

ω Centauri, in the southern hemisphere, is a closely compressed cluster of thousands of stars. It may be seen without telescopic aid as a hazy star of the fourth magnitude. In the southern hemisphere also are situated two curious objects, the Magellanic clouds, which comprise within their bounds stars, star-clusters, and nebulæ.

The Galaxy.—The star-clusters, however, are merely subordinate systems within a greater system. This greater system is the agglomeration of stars, variously known as the Universe, the Stellar Universe, and the Galaxy; and perhaps the second of these names is the most suitable. The ground-plan of the Stellar Universe is the belt of milky light

known as the Milky Way or Galaxy; the Milky Way may be seen on any clear moonless night spanning the heavens like a great arch. It traverses the constellations of Scorpio, Sagittarius, Aquila, Cygnus, Cepheus, Cassiopeia, Perseus, Auriga, Gemini, Canis Major, Monoceros, Argo Navis, Crux, Ara, and Centaurus. The Milky Way has been known from the earliest ages, and was the subject of much speculation by the ancient Greeks. Aristotle considered that it was due to atmospheric vapours; Anaxagoras believed it to be the shadow of the Earth. Democritus, Manilius, and Pythagoras, however, advanced the view that it was no more than an agglomeration of very faint stars, and this hypothesis was fully confirmed by Galileo. For centuries the Galaxy has arrested the attention of observers of nature, and it is referred to in numerous poetical works. Wordsworth calls it "Heaven's broad causeway paved with stars," and Milton refers to it as

> "A broad and ample road, whose dust is gold
> And pavement stars, as stars to thee appear,—
> Seen in the Galaxy, that Milky Way,
> Which nightly, as a circling zone, thou seest,
> Powdered with stars."

Study of the Galaxy.—Galileo made a special study of the Milky Way, but of course his telescope was of little use in resolving the fainter portions into stars. There were parts of the Galaxy," writes Mr Peck,

"that Galileo's telescope utterly failed to penetrate, and there still remained in the background that same misty light which had for so many centuries engaged the attention of astronomers. With every increase of telescopic power more stars were seen and greater depths were reached, but only to find, as Galileo had found, that still some parts would require a more powerful instrument to reveal the individual stars that by being so closely crowded together caused this cloudy light. And even when Sir William Herschel applied his powerful reflectors to this part of the heavens and reached still further depths, there was yet seen that same milky light which speaks of the myriads of stars still to be revealed. Nay, even Lord Rosse, with his gigantic telescope, could not resolve some of the luminous patches scattered throughout the Milky Way."

Photography of the Milky Way.—In recent years the Galaxy has been very successfully photographed by three able astronomers—the late Dr Isaac Roberts, Professor Barnard, and Professor Max Wolf. The result of these photographs has been to show that in portions the stars are closely intermixed with nebulous matter. A remarkable feature of the Galaxy is the existence in it of dark rifts and chasms. A typical chasm is "the coal-sack" in the constellation Crux in the southern hemisphere; but there are many others, and Dr Wolf's photographs have revealed many

smaller rifts which were previously unknown. Through these rifts we seem to get a view into the depths of space beyond the Galaxy, into the region which has been designated "the darkness behind the stars."

Theories of the Galaxy.—The first theory of the constitution of the Galaxy was put forward in 1760 by an English astronomer, Wright of Durham, and independently by Herschel in 1786. Even with a small telescope it is apparent that there are more stars in the region of the heavens crossed by the Milky Way than in the regions farthest from that zone; and the stars increase regularly up to the Galaxy. Herschel put forward the theory that the stars were uniformly distributed throughout space, and explained the brightness of the Galaxy by supposing that the stars extended much farther in that direction. This theory—known as "the disc theory"—supposed the Universe to have the form of a cloven disc. In the course of his researches Herschel found that there were many instances where the stars were not uniformly distributed, and accordingly he abandoned the disc theory in 1811.

Since Herschel's day there have been many theories advanced to explain the Milky Way and its relation to the Universe. Struve, Proctor, Seeliger, and Celoria have each advanced explanations. Within the past half-century it has been shown that the

aggregation of the stars on the Galaxy is by no means confined to the telescopic stars. Schiaparelli has shown that the lucid stars—those visible to the unaided eye—also cluster on the Galaxy. Thus, in the words of Seeliger, "The Milky Way is no mere local phenomenon, but is closely connected with the entire constitution of our Stellar System."

The Stellar Universe.—The prevalent idea seems to be that the Stellar Universe forms a globe of stars, and that the Milky Way is the equatorial zone of that globe; that there is greater clustering in the Galaxy than elsewhere in the Universe; and there may be also greater extension in the line of sight.

Motions of the Stars.—But the stars of the Universe—of which our Sun is one—are not at rest. They are all moving, some of them with enormous velocities; and the question comes to be, Whither are they going, and are they moving round some centre? It used to be a favourite idea that the stars were in revolution round some great centre. Mädler thought he had evidence that the star Alcyone, in the Pleiades, was the central sun; Argelander of Bonn suggested that the central body was situated in Perseus. These theories, however, have not been proved, and so far as our knowledge goes, there would seem to be no star in the Universe large enough to compel the others to move round it.

Flammarion compares our Solar System to an absolute monarchy with the Sun as despot, and the Stellar Universe to a federative republic without a dominating authority.

Although no law of motion in the Stellar Universe has been discovered, several local peculiarities have been disclosed. Thus, it has been shown that blue stars of the first spectral type are most prevalent on the galactic zone; while, according to Professor Kapteyn's investigations, the near vicinity of the Sun contains almost exclusively stars of the solar type. The stars of the constellation Orion, too, have, with the exception of Betelgeux, similar spectra, and betray affinities to the great Orion nebula. Local peculiarities of motion are also apparent, such as the drift of the stars of the Plough, and the common proper motion of the stars of the Pleiades. Recently, too, Professor Kapteyn has disclosed the existence of two great streams of stars moving in opposite directions. But, as Mr Gore has well remarked, "The Copernicus of the Sidereal System has not yet arrived, and it may be many years or even centuries before this great problem is satisfactorily solved."

A Limited Universe.—What of the extent of the Universe? There is fairly strong evidence that, however great its extension, our Stellar Universe is not infinite. There is a well-known law of optics which stipulates that were the stars infinite in

number the whole heavens would shine with the brightness of the Sun, resulting from the combined light of an infinite number of stars. In some parts of the Universe, too, the limits seem to have been reached. Notably is this the case at the north galactic pole, where Celoria of Milan, with a small telescope, could see as many stars as could Herschel with his great refractor. Whatever its extension, our Universe appears to be limited. It is "a point in the Infinite."

External Universes.—But our Universe is not *the* Universe. It is difficult to conceive of space either as finite or infinite; but the latter conception is easier than the former. And if space is infinite, there must be more stellar systems, external universes. We have never seen such systems, but in infinite space there would be an infinite number of systems such as our own vast Stellar Universe—systems containing hundreds of millions of stars, each of them probably accompanied by inhabited planets, and of such an enormous extension that light would require about twenty thousand years to cross from one boundary to the other.

Mr Gore has calculated the distance of the nearest of these possible external universes, and he finds it to be 520,149,600,000,000,000,000 miles! We can easier conceive this enormous distance by considering the velocity of light. Light reaches us from the

Sun in eight minutes, and from Arcturus in two hundred years, and, according to reliable calculations, takes about twenty thousand years to cross the diameter of the Stellar Universe. And light, travelling at the enormous, unthinkable velocity of 186,000 miles a second, would take nearly ninety millions of years to pass from the nearest external universe to our Universe. And this is the minimum distance at which such a universe could be situated. The mind is absolutely overwhelmed with such calculations; as Richter says, "the spirit of man acheth with this infinity." It is inconceivable; and yet it is a fact that our Universe is only one little island in the shoreless ocean of infinite space.

Infinity and Eternity.—Does not such a thought lift our minds from the material Universe—grand, splendid, and magnificent though it be—to the Almighty and Omnipresent Creator and Designer of this glorious Cosmos, the Everlasting Spirit who creates and sustains the whole? "By the word of the Lord were the heavens made; and all the host of them by the breath of His mouth." Astronomy teaches us in a new light the enormous extent of the material creation, and the insignificance of this little grain of sand on which we live; it gives us a nobler conception of the Infinity and Eternity of God, and the feebleness and nothingness of man; and by its aid we discern a deeper meaning in the

words of the Psalmist: "When I consider Thy heavens, the work of Thy fingers, the moon and the stars, which Thou hast ordained; what is man, that Thou art mindful of him, and the son of man, that Thou visitest him?"

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THE END.

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